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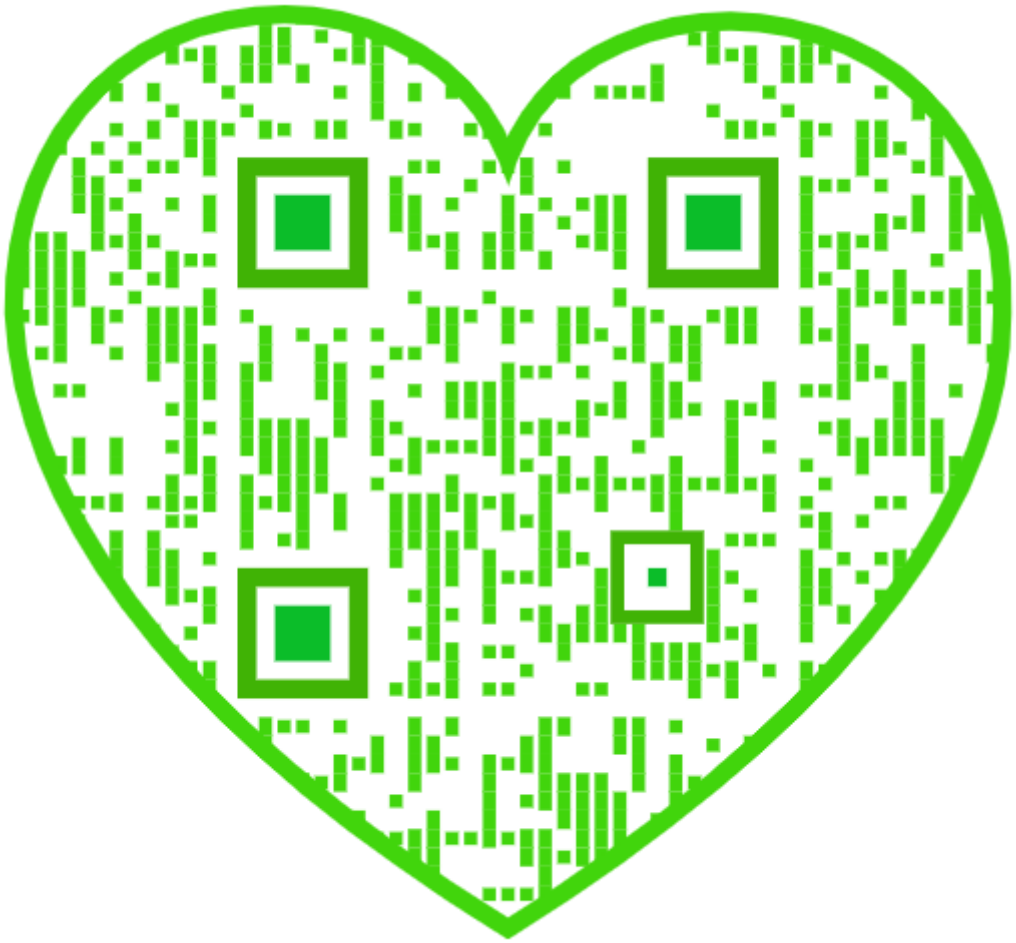
HOW THE MOON MOVES
CONFESSIONS OF AN AURORA IMAGER
COMPLETE SKY EVENTS COVERAGE

BONUS ONLINE CONTENT CODE p. 3

Vol. 53 • Issue 6



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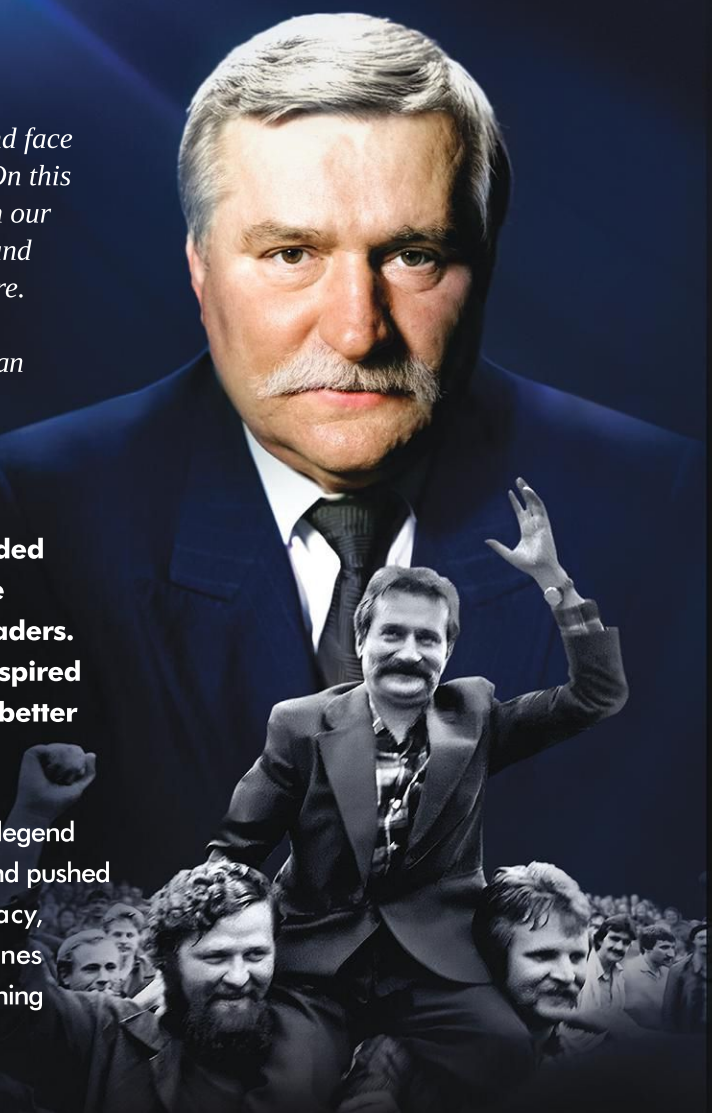

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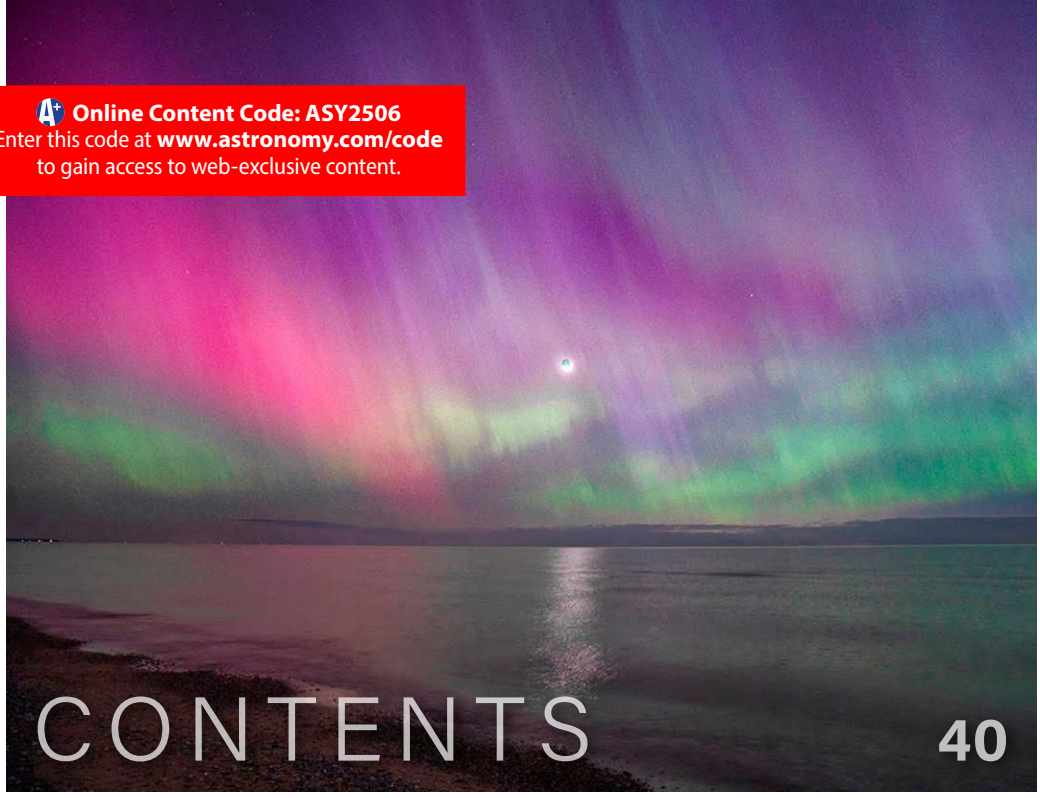

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Johannes Kepler's manuscript *In Somnium Astronomicum* (or *An Astronomical Dream*) was published posthumously, and is the first work on lunar astronomy and the first science fiction book. ALAN DYER

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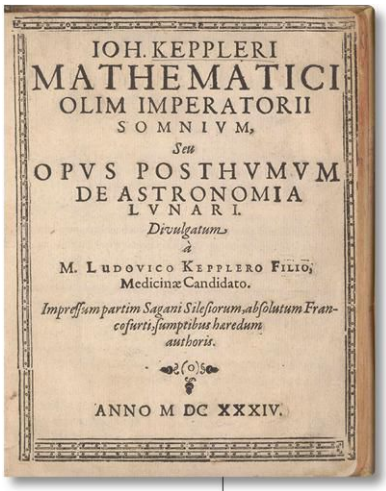
Kepler's legacy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ANNO M DC XXXIV.

ABOVE: The title page of *In Somnium Astronomicum* indicates the book was published posthumously in 1634 by Ludwig Kepler, Johannes Kepler's son. LIBRARY OF CONGRESS, RARE BOOK AND SPECIAL COLLECTIONS DIVISION

RIGHT: Within his tale of two humans brought to the Moon by a daemon, Kepler illustrated his scientific ideas on the dynamics of the Earth-Moon system, including lunar phases and eclipses. LIBRARY OF CONGRESS, RARE BOOK AND SPECIAL COLLECTIONS DIVISION

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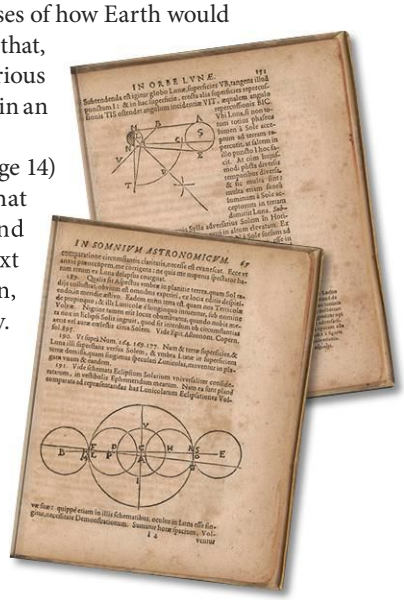
Fourteen years ago, on a trip with *Astronomy* readers, I traveled to (among many other places) Johannes Kepler's house in Prague. Not only is Prague's astronomical history mind-blowing — you can look up at the same astronomical clock Kepler and Tycho Brahe stared at — but understanding Kepler's legacy occurs in no better location.

In recent years, Kepler's name has been typically attached to the space telescope bearing his heritage that opened the door to understanding the commonality of planets surrounding other stars in the galaxy. We owe so much to him, though.

Kepler lived from 1571 to 1630, overlapping with Tycho, Galileo, and many others in a crucial time in the history of astronomy. His three laws of planetary motion cemented our understanding of the mathematical precision of orbits, of the fact that laws and not superstition govern the cosmos. He paved the way, in that sense, for the Newtonian Revolution that followed. And he accomplished much beyond that in a relatively brief lifetime of 58 years, too much to mention here.

But his parting shot was particularly vivid. His novel *Somnium*, Latin for *The Dream*, is arguably the first science fiction book ever written in the modern world. Composed in Latin in 1608, the book was first published by Kepler's son Ludwig in 1634, a few years after his father's death. In the book, an Icelandic boy and his mother, a witch, learn of an island that represents the Moon, and the story progresses from there, including detailed analyses of how Earth would look from the Moon. Because of that, it is in some senses the first serious description of lunar astronomy in an analytical way.

Enjoy Fred Nadis' story (page 14) on this revolutionary work that changed science forever and launched science fiction. The next time you gaze up at the Moon, you may see it in a different way.



Yours truly,

David J. Eicher
Editor-in-Chief

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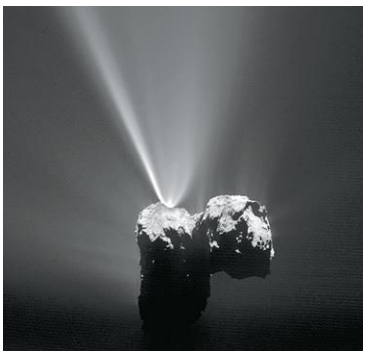

Several bright jets spew from the surface of Comet 67P/Churyumov-Gerasimenko.
D. ROMEUF (UNIVERSITY CLAUDE BERNARD LYON 1, FRANCE); IMAGES: ESA/ROSETTA/MPS FOR OSIRIS TEAM MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

We welcome your comments via email to **letters@astronomy.com**. *Please include your name, city, state, and country. Letters may be edited for space and clarity.*

Ask Galileo

I would like to thank you for Henry Hsieh's answer to my Ask Astro question concerning comets losing mass, in the January 2025 issue. His response was very informative. If I had thought a little more before asking, I would have realized that Galileo answered that question many, many years ago with his experiments off the Pisa Tower. **—Robert Bailey,** Conover, WI

Moon miss?

The Artemis 3 lunar landing plan outlined in the January 2025 issue reads less like a blueprint for exploration and more like a Rube Goldberg machine in space. Between the reliance on tanker launches to refuel a depot, a rocket that can't meet its payload targets, and a timeline that's already slipped years behind schedule, one has to wonder: Is NASA planning a Moon mission or a logistical endurance test? And while the article cautiously notes the delays and underperformance, it understates the sheer scale of what could go wrong. NASA and their partners should focus less on ambitious timelines and more on developing a plan that doesn't feel like it's being held together by duct tape and hope. **—Jeff Phillips,** Saskatoon, SK

Rave review

I enjoyed reading Phil Harrington's article on the Seestar S50 (January 2025). I was first introduced to the Seestar quite by chance.

I was never a "photography guy." After traveling to Nashville, Tennessee, for the 2017 eclipse, I came away empty-handed. I had no pictures to share, and trying to convey what I saw to others fell flat. I vowed to do better for the 2024 eclipse. I had been observing with my 6-inch Celestron, but realized this would not be able to capture the eclipse; the focal length would crop the Moon. I happened to see a video of the Seestar S50 and bought one. The price was great, and if it could really take pictures of the eclipse, it would be a win-win. I imaged the Sun, Moon, and M42 the first day I had it. I continued practicing and ended up with great pictures of the eclipse from Kerrville, Texas, even with the overcast skies. **—Craig Steele,** Brea, CA

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SNAPSHOT

EUCLID SPIES AN EINSTEIN RING

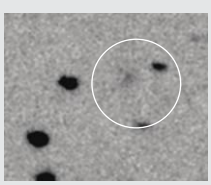
Created by gravitational lensing, the ring was buried in a well-known galaxy.

Gravitational lensing occurs when a massive foreground object — such as galaxy NGC 6505, central in this image and only 590 million light-years from Earth — bends and magnifies light from an object behind it, acting like a magnifying glass. In this case, the result is a ring of smeared-out light from a galaxy some 4.4 billion light-years away, far beyond NGC 6505. Although NGC 6505 has been observed since 1884, the European Space Agency's Euclid mission discovered the ring (enlarged in the inset) in test data taken in September 2023, proving the mission's mettle.

Gravitational lensing often produces arcs or smears. The perfect alignment — as in this case — that produces a clearly defined ring, called an Einstein ring, is rarer. Such rings are particularly valuable, as astronomers can use them to work out the properties of the lensing galaxy — including its dark matter — and even details about the expansion of the universe that has occurred as the light has traveled to us. –ALISON KLESMAN

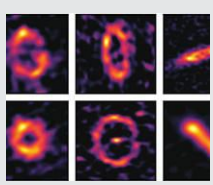
ESA/EUCLID/EUCLID CONSORTIUM/NASA, IMAGE PROCESSING BY J.-C. CUILLANDRE, G. ANSELMI, T. LI. BOTTOM FROM LEFT: MICHAEL JÄGER; NASA/SVS/ERNIE T. WRIGHT; LUCA MATRÀ

HOT BYTES



FAR OUT
Comet C/2025 D1 (Gröller) has the farthest perihelion of any comet ever found. Spied Feb. 20 by Hannes Gröller at over 15 astronomical units (AU, the average Earth-Sun distance) away, it already shows a visible tail. Its closest approach to the Sun will be 14.1 AU.

FAST FORMATION
The Moon's Vallis Schrödinger (at left) and Vallis Planck (upper right) — both the size of Arizona's Grand Canyon — were blasted out in just 10 minutes by streams of debris from the impact that formed Schrödinger Basin (lower right), according to new simulations.



ALIEN ICEBALLS
Radio observations from Hawaii's Submillimeter Array and the Atacama Large Millimeter/submillimeter Array in Chile have revealed comet belts around 74 stars. The belts are similar to our solar system's Kuiper Belt.

BLUE GHOST LANDER ACES MOON MISSION

Firefly Aerospace nailed a lunar landing on its first try, succeeding where many startups have failed.

SILHOUETTE SELFIE. Shortly after landing, Blue Ghost sent back this stunning photo of its own shadow with Earth above the lunar horizon. FIREFLY AEROSPACE

For Firefly Aerospace, first time was the charm. The company's Blue Ghost lunar lander touched down flawlessly on March 2, 2025, and operated for two weeks at Mare Crisium, wrapping up on March 16.

It was a smashing success of a mission for the company based in Austin, Texas — made all more impressive for being its first attempt at landing on the Moon. Even 55 years after Apollo, robotic lunar landings remain risky and difficult, as evidenced by failed Moon missions from Russia and India, as well as doomed private efforts from U.S., Israeli, and Japanese landers.

Firefly's perfect start was welcome news to NASA, which paid the company $93.3 million to deliver a suite of scientific payloads as part of the agency's Commercial Lunar Payload Services (CLPS) program. Of four CLPS missions flown to date (including two by Intuitive Machines), Blue Ghost Mission 1 is the only one that has been fully successful.

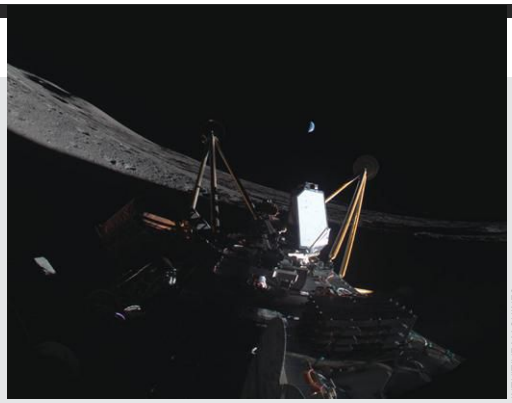
Blue Ghost launched atop a Falcon 9 rocket on Jan. 15, 2025, spiraling away from Earth in an energy-saving trajectory before dropping into lunar orbit on Feb. 13. Over the next 17 days, the craft lowered itself into a 62-mile-high (100 kilometers) circular orbit. At 2:34 A.M. CST on March 2, the 6.6-foot-high (2 meters) gold-foil-covered lander touched down autonomously near Mons Latreille on eastern Mare Crisium.

Landing footage revealed Blue Ghost's shadow at an altitude of 91 feet (28 m) as it descended, followed by violent swirls of dust whipped up by rocket exhaust. When the engines shut off, the dust settled remarkably quickly in the airless lunar environment.

Upon touchdown, the first of the 10 lunar surface experiments was already a success. NASA's Stereo Cameras for Lunar Plumes Surface Studies (SCALPSS) captured 3,000 frames of video showing how the rocket exhaust interacted with the loose lunar dust and regolith. These observations will aid mission planners in the Artemis crewed landing later in the decade.

A science highlight was the Lunar Magnetotelluric Sounder (LMS) experiment developed by the Southwest Research Institute in San Antonio. Video showed Blue Ghost hurling LMS's softball-sized magnetotelluric

IM-2 falls flat



INTUITIVE MACHINES

Just four days after Blue Ghost's successful landing, Houston-based Intuitive Machines attempted to land March 6 with its IM-2 mission at Mons Mouton — the southernmost lunar landing site ever. But upon touchdown, mission controllers couldn't confirm the lander's orientation. Images released the next day revealed the craft had toppled onto its side in a shadowed crater. The frigid cold and lack of sunlight meant the solar panels couldn't charge quickly enough to maintain power. This followed the company's February 2024 mission, IM-1, which also suffered a hard landing, breaking a leg and settling at an angle.

IM-2's surface mission — scheduled for 10 days — lasted barely 13 hours before depleting its batteries. Because of the lander's orientation, it also couldn't operate its main payload, a drill built by NASA that was meant to prospect for lunar ice (although it did test its range of movement). And a rover and a small drone remained trapped aboard, unable to be deployed. — SAMANTHA HILL

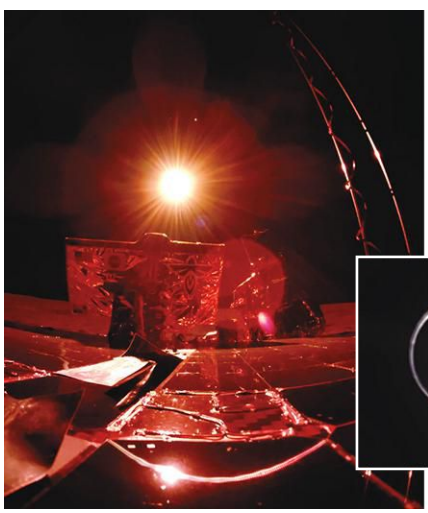
sensors more than 60 feet (18 m) from the lander. By measuring the variation in electrical and magnetic fields across the Moon's surface, LMS aims to study how the Moon's interior cooled and its minerals were distributed.

The mission also tested NASA's Electrodynamic Dust Shield, experimental technology to sweep lunar dust away from vital spacecraft and spacesuit components, addressing a growing concern for future lunar exploration. And the Italian Space Agency's Lunar GNSS Receiver Experiment successfully detected signals from GPS and European Galileo navigation systems, proving that familiar navigation technology can also guide lunar explorers.

The Blue Ghost lander performed two experiments that touched and sampled the lunar surface. The Lunar PlanetVac experiment prepared by Honeybee Robotics demonstrated a technique to gather regolith samples using pressurized nitrogen gas. And in a Honeybee collaboration with Texas Tech University, the Lunar Instrumentation for Subsurface Thermal Exploration with Rapidity experiment successfully drilled into the lunar regolith to place a temperature probe.

The lander even observed the March 14/15 total lunar eclipse, which from its perspective was a total solar eclipse. As Earth slowly passed in front of the Sun, the lander was bathed in the eerie red glow of Earth's umbral shadow and temperatures plunged from 104 to –274 degrees Fahrenheit (40 to –170 degrees Celsius).

The Blue Ghost lander was not expected to survive the lunar night, but its scientific legacy will keep researchers busy for a long time. — ROBERT REEVES



PERSPECTIVE SHIFT. During the March 14/15 total lunar eclipse, sunlight was refracted around our planet's limb by the atmosphere. This bathed the Blue Ghost lander with an eerie reddish glow and caused Earth to appear as a ring in the lunar sky. As it reappeared from behind Earth, the Sun created a classic diamond-ring effect (inset). FIREFLY AEROSPACE

QUICK TAKES

EARTH DODGES CITY-KILLER

In mid-February, the near-Earth asteroid 2024 YR4 — discovered Dec. 27, 2024, and estimated at between 130 and 300 feet (40 to 90 m) wide, comparable to the Tunguska impactor — briefly reached a probability of over 3 percent of striking Earth in 2032, NASA said. But additional data eventually ruled out an impact.

PUNCHING ABOVE ITS MASS

Astronomers have found a radio jet spanning over 200,000 light-years — twice the Milky Way's width — bursting from the center of the distant galaxy J1601+3102. Despite being powered by a relatively puny central black hole, it's the largest such jet ever seen in the early universe.

EARTH'S NEW BELT

The solar storm of May 2024 — the strongest in 20 years — created two radiation belts between the permanent Van Allen belts, per NASA CubeSat data. One belt of energetic protons likely persists today, posing a potential hazard to satellites ascending to geostationary orbit.

GET YOUR HANDS DIRTY

Astronauts often suffer from immune issues and skin rashes on the International Space Station. A Feb. 27 study in *Cell* of 800 surface samples reveals the ISS is overly sterile with extremely low microbial diversity. Scientists suggest introducing natural soil and water microbes could improve astronauts' health.

PANCAKE LENS

University of Utah researchers have designed and fabricated a 4-inch f/2 telescope primary lens that is flat and lightweight, focusing light with microscopic diffractive rings instead of a curved mirror or lens. The prototype can resolve lunar features and sunspots.

— MARK ZASTROW

Trump lays siege to space science

NEXT STOP, MARS? The U.S. flag flies alongside the NASA, International Space Station, and Progress Pride flags at the Mary W. Jackson NASA Headquarters Building in June 2022. NASA/JOEL KOWSKY

Two months into U.S. President Donald Trump's second term, astronomers and space scientists are living in a state of fear and anxiety as the administration and Elon Musk-led U.S. DOGE Service target science spending and diversity initiatives. Scientists say their actions are already damaging research and threaten to set back U.S. scientific leadership for years.

On March 10, NASA announced an initial round of job cuts, eliminating 23 positions and closing three offices: the Office of the Chief Scientist, led by climatologist Katherine Calvin; a Diversity, Equity, and Inclusion (DEI) office; and the Office of Technology, Policy, and Strategy. The cuts are expected to be followed by more sweeping layoffs, hinted at by a NASA spokesperson in an internal memo first reported by the website *NASA Watch*.

The Trump administration argues it's trying to right-size a bloated federal bureaucracy. But its restrictions on government agencies and scientists have also led to "a terrible, inefficient waste of resources," said one space scientist who requested anonymity for fear of reprisal. The administration has effectively frozen government purchase cards — credit cards used by agencies to purchase supplies and equipment — by setting their spending limits to $1. "We're trying to build spacecraft … and can't buy anything," said another space scientist. "That's really stupid s---." (More than a dozen other scientists contacted by *Astronomy* declined comment.)

Trump has vowed to send astronauts to Mars to plant the U.S. flag. In a push for human exploration, science could lose out.

On March 7, The Planetary Society issued a statement responding to reports that the Trump administration's proposed 2026 budget would cut NASA's Science Mission Directorate (SMD) budget by 50 percent. That would be an "extinction-level event" for U.S. space science, said the society's policy advocate Casey Dreier.

The missions most at threat, said Dreier, are those that have exceeded their design goals and continue to perform good science. These include the Voyager probes; the New Horizons spacecraft, which flew by Pluto in 2015 and is exploring the Kuiper Belt; and the Hubble Space Telescope.

Funding for research is also vulnerable. About 25 percent of SMD's budget goes to scientific research and grants, according to Dreier, funding scientists and students across the country.

"There's nothing in the Constitution that says we have to do space science," warned Dreier. "It is a choice. If we elect not to do it, it says something very sad about our society. Then we've lost a consensus in the role of public investment in science."

— CHRISTOPHER COKINOS

ESO/VVVX SURVEY

Stars and gas shine in RCW 38

Some 5,500 light-years away lies the star cluster RCW 38. Less than a million years old, the cluster is home to about 2,000 young suns — and counting. Star-forming regions such as this are swathed in gas and dust; as denser regions conglomerate and collapse under their own gravity, new stars are born. ESO's Visible and Infrared Survey Telescope for Astronomy (or VISTA) captured this image in infrared light, cutting through much of the dust that obscures visible-light observations. It shows numerous young stars within the cluster, some still wrapped in dusty shrouds. Meanwhile, the glowing gas, highlighted here in hues of pink, is energized by the numerous young stars, which throw out vast amounts of high-energy radiation in this early stage of life. — A.K.

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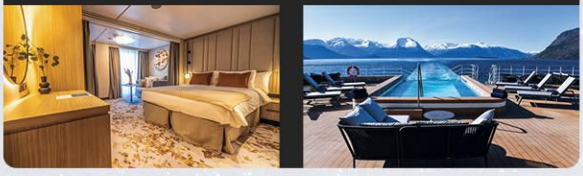

AUGUST 2026

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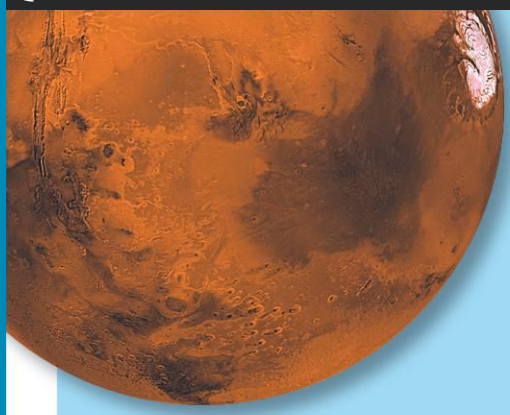

WERE WE WRONG ABOUT MARS' RED COLOR?

RUST-COVERED. Mars' red color is due to iron oxide, otherwise known as rust. But rust comes in several forms, and new research indicates Mars' color may come from ferrihydrite, which forms in cool, wet conditions. NASA/JPL/USGS

WE'VE ALWAYS KNOWN MARS as the Red Planet — but we may have been wrong about the reason *why*. A study published Feb. 25 in *Nature Communications* ties the red tint to ferrihydrite — a type of iron oxide (rust) that forms in water-rich environments, hinting at Mars' wet past. Previous models suggested the culprit was hematite, an iron oxide that forms in dry conditions.

According to study lead author Adomas Valantinas, a postdoctoral fellow at Brown University, ferrihydrite typically forms in cool environments with roughly neutral pH levels ripe for oxidation. This suggests early Mars was a cold and wet environment, says Valantinas.

Various iron oxides reflect different wavelengths of light. By combining observations from a number of orbiter and rover missions, Valantinas' team discovered that ferrihydrite is the predominate species of iron on the martian surface. The data also indicate that ferrihydrite may have come to dominate about 3 billion years ago. Valantinas says that during this period, called the Hesperian era, intense volcanic activity was likely melting surface ice, triggering intense flooding. The Hesperian also marked the turning point in the planet's history where surface water began to disappear.

"The timing aligns with a period when Mars was transitioning from its earlier, wetter state to its current desert environment," Valantinas says. Understanding the conditions in which the ferrihydrite formed will help piece together the history of Mars, including its habitability.

Valantinas says the Mars Sample Return mission will allow direct measurement of the amount of ferrihydrite, which "could reveal the water temperature in which ferrihydrite formed, the water's source … and potentially even whether microbes played a role in ferrihydrite formation." — JOHN WENZ

The most energetic neutrino yet

ON FEB. 13, 2023, deep beneath the Mediterranean Sea, KM3NeT's Astroparticle Research with Cosmics in the Abyss (ARCA) telescope saw the telltale sign of a rare cosmic messenger. Known as a neutrino, the particle had an estimated energy of 220 peta-electron volts (PeV) — the most energetic neutrino ever detected. Its discovery was published Feb. 12 in *Nature*.

Neutrinos are elusive: They have no electric charge, barely any mass, and can pass through planets. KM3NeT (short for the Cubic Kilometer Neutrino Telescope) is anchored to the seafloor off the southeastern coast of Sicily. Strings of glass spheres packed with photodetectors lie in wait for faint flashes of light, called Cherenkov radiation, emitted when a high-energy particle created by a neutrino hitting a water molecule zips by faster than light moves in water.

This neutrino likely struck 6 to 19 miles (10 to 30 km) away, creating a muon that streaked through the detector, tripping more than a third of the sensors. "This was a super-duper mega event," says Paschal Coyle of the French National Centre for Scientific Research. "The neutrino's energy was off the charts."

The KM3NeT team is still narrowing down the exact point on the sky where the neutrino came from, but there are three active galaxies in its general direction that were flaring at the time, says Coyle. If the team traces the neutrino back to one of them, it was likely generated by some process driven by the galaxy's central black hole.

But if it can't be traced back to one of those galaxies, its high energy suggests it could be the first detection of a cosmogenic neutrino — one created when a cosmic ray interacts with a low-energy photon of the cosmic microwave background from the Big Bang. Although these have not yet been seen, they could shed light on many aspects of our universe.

Either way, this neutrino is a landmark discovery. "It's a completely unexplored energy range," Coyle says. "We don't know what to expect, and that's the most exciting part." — ANANYA PALIVELA

MANY EYES. KM3NeT consists of long strings with spheres full of photodetectors, all anchored to the seafloor. They continually monitor for the flashes of light produced when a neutrino hits a water molecule, as occurred in February 2023. KM3NET

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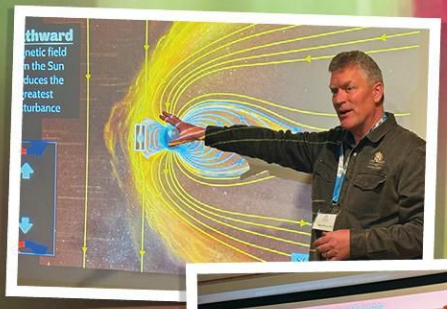

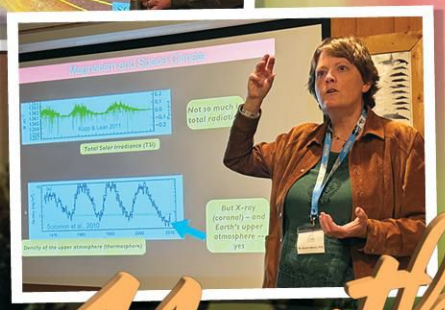

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Experience Kepler's *Astronomical Dream*

This fanciful yet scientifically guided tale is considered the first true work of science fiction. BY FRED NADIS

Four centuries ago, Johannes Kepler established three laws of planetary motion that accurately describe how planets in the solar system orbit the Sun. That might be enough for most; however, befitting the Renaissance period in which he lived, Kepler also revised the field of astrology, wrote a treatise on optics, established the field of crystallography with an essay on snowflakes, rhapsodized about universal harmonies, made a volumetric study of barrel shapes used in transporting wine, proposed calendar reforms, and cast horoscopes. But perhaps his most underappreciated accomplishment was writing what some deem the first work of true science fiction.

Kepler's *In Somnium Astronomicum* (*An Astronomical Dream*), which depicts a journey to the Moon, went unpublished in his lifetime but was not exactly an afterthought. He worked on it throughout his career, beginning in his student days in the 1590s, and he had it typeset before his death. While it's far from his most important accomplishment, *Somnium* does offer a peek into Kepler's wild and wonderful mind.

Written around the turn of the 17th century, *In Somnium Astronomicum* imagines a strange journey to the Moon and what one might find there. EVGENY OSTROUSHKO/DREAMSTIME.COM

Origin story

Destined for fame, if never quite for fortune, Kepler was born in 1571 in Weil der Stadt, Germany, into the artisan class. His father, Heinrich, a brutal and destructive man, abandoned the family and became a mercenary soldier. His mother Katharina was an uneducated and allegedly quarrelsome woman who dabbled in herbal healing. His grandfather Sebald, the town mayor, arranged for the sickly youth's education at the University of Tübingen, a Lutheran seminary near Stuttgart.

At Tübingen, he studied theology, philosophy, and mathematics. His teacher, Michael Maestlin, quietly supported the Copernican heliocentric model of the universe. Both Catholic and Protestant authorities rejected Copernicanism as anything more than a model for calculation. Kepler, however, did not doubt its truth. At Tübingen, he proposed a dissertation on the question: "How would the phenomena

occurring in the heavens appear to an observer stationed on the Moon?" A key point was that an observer on the Moon would not sense the Moon's motion. This addressed Copernicus' critics who insisted Earth could not move or those on it would see and feel its disruptive effects. Kepler's advisor, Veit Muller, refused to give this dissertation a public forum, but it later formed the kernel of *Somnium*.

Within a decade of finishing his studies, Kepler sent the famed astronomer Tycho Brahe a copy of his first book, *Mysterium Cosmographicum* (1597). Brahe wrote to Kepler that he took "unusual pleasure" in the concepts laid out in it, and invited Kepler to visit, then to work with him.

Collaborating with Brahe, however, was frustrating. At Brahe's castle outside Prague, Kepler was an underling, allowed only glimpses of Brahe's superb but carefully guarded astronomical data. It was only with Brahe's death, when Kepler became Brahe's successor as imperial mathematician, that he finally gained full access to Brahe's observations and instruments. This provided the data to scaffold his groundbreaking theoretical work. In 1605, Kepler determined from Brahe's observations his first law — that Mars' orbit was not a circle (as Copernicus believed) but an ellipse. He published this theory, along with his second law, describing a planet's varying speeds in different portions of its orbit, in *Astronomia Nova* in 1609.

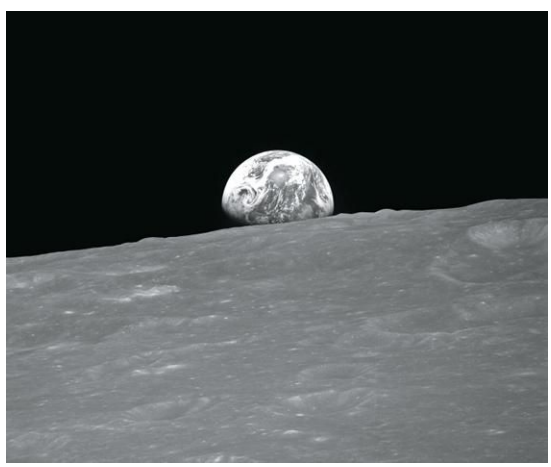
The Moon again loomed large for Kepler in 1610 when he received a copy of Galileo Galilei's *Sidereus Nuncius* (or *Starry Messenger*). Relying on the then-novel telescope, Galileo announced his sharpened observations of the Moon's features, and his discovery of four of Jupiter's moons and numerous previously unseen stars. Kepler, delighted, wrote a book-length response. The enormity of the Moon's mountains and valleys that Galileo observed led Kepler to speculate that its inhabitants, if any, were also enormous.

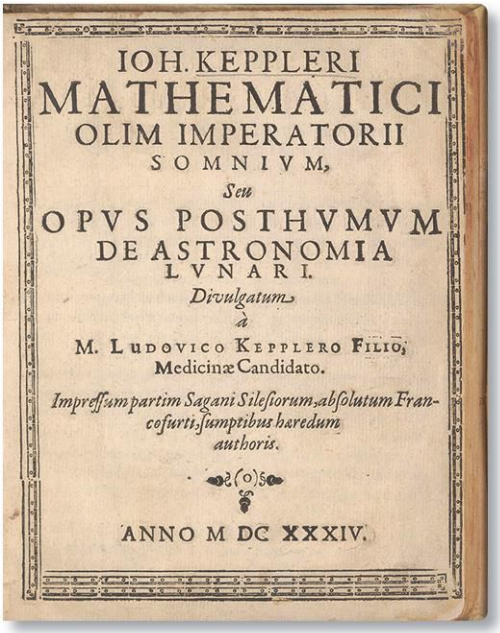
Kepler was astonished that one large crater on the Moon perfectly took the shape of a circle. He could think of no natural ways such a crater could have formed — neither wind nor water erosion could explain this geometric form. He speculated in what he called "playful remarks" that perhaps Moon dwellers had excavated regolith to create circular ramparts that provided recessed areas where they could escape from the sunlight,

TOP: Johannes Kepler, depicted here in an engraving made centuries after his death, was a true Renaissance man who worked in a variety of fields, including astronomy, astrology, and music. GEORGIOS KOLLIDAS/DREAMSTIME.COM

BELOW LEFT: Kepler's tale accurately takes into account the extreme temperature differences between the portions of the Moon's nearside in sunlight and shadow. His lunar inhabitants have hides designed to protect them, and often take refuge underground. ALAN DYER

BELOW RIGHT: In December 1968, Apollo astronaut Bill Anders snapped the iconic series of Earthrise images, showing Earth rising over the lunar horizon as their spacecraft orbited our satellite. More than 300 years earlier, Kepler described how Earth might appear in the sky to those living on the nearside of the Moon. NASA

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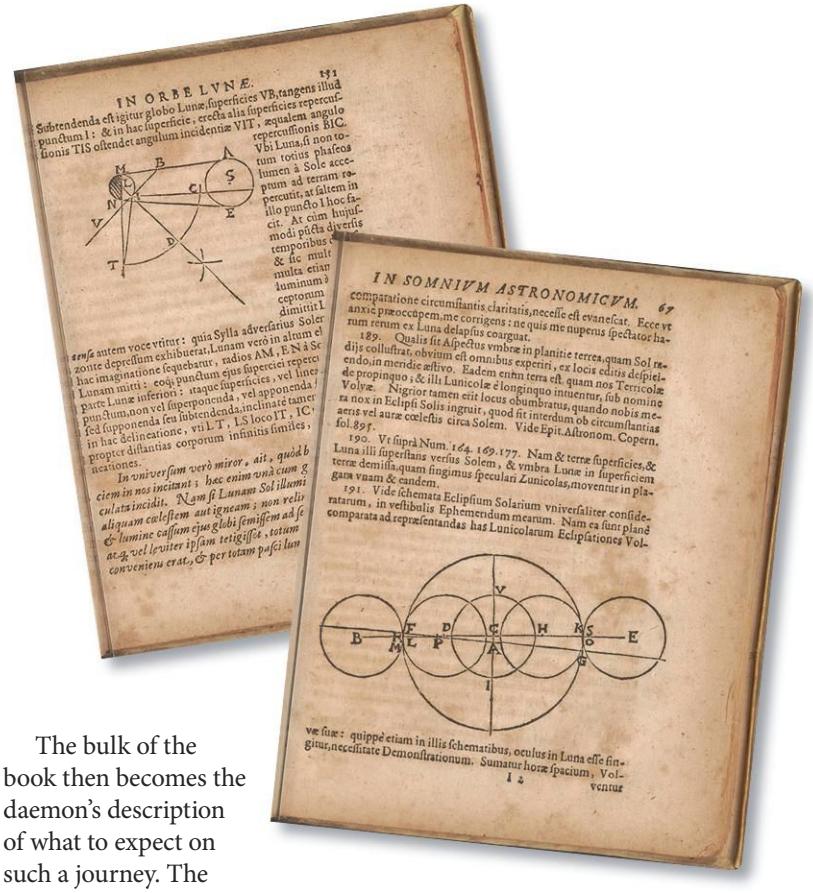

IN ORBE LVNÆ.
IN SOMNIVM ASTRONOMICVM.

moving as necessary. "They have as it were an underground city. … They place their fields and pastures in the middle."

Even before reading Galileo's study, Kepler was turning his dissertation on lunar geography into *Somnium*. Its unnamed narrator, after observing the stars and Moon, falls asleep reading a history of Bohemia. In his dream, he opens another book about a young hero, Duracotus, for whom magic and science are dual sources of knowledge.

Once upon a time

As a child, Duracotus, the son of Fiolxhilde, lives in Thule (modern-day Iceland). His mother packages herbs in goatskin bags that sea captains value as protection on journeys. When Duracotus cuts open a bag to inspect it, a furious Fiolxhilde sends him off with a sea captain who has him deliver a message to Tycho Brahe. The narrator becomes enthralled with astronomy and joins Brahe's assistants. When he later revisits his mother in Thule, she tells him that she can evoke a spirit or daemon that can transport her to or tutor her about distant lands, including the "island of Levania" (the Moon). He is all in.

Fiolxhilde summons this spirit at a crossroads. When she and Duracotus cover their heads with their cloaks, the spirit speaks to them and explains that not all humans are fit for transport to Levania. The spirits will take "nobody who is lethargic, fat, or tender." In a jesting reference to witchcraft, the daemon adds, "We especially like dried-up old women, experienced from an early age in riding he-goats at night or forked sticks."

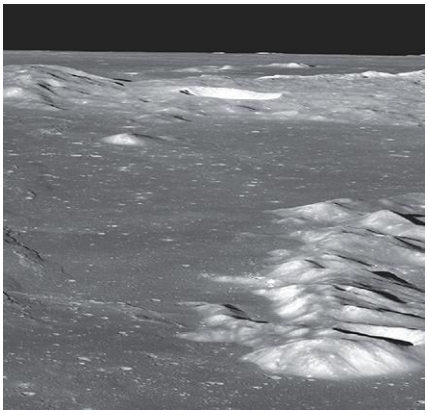
The bulk of the book then becomes the daemon's description of what to expect on such a journey. The daemons place damp sponges on travelers' faces to help them endure the ensuing cold of space and "impeded breathing." They also administer narcotics to ease travel. With a push from the daemons, the voyagers explode from Earth as if shot by gunpowder. Soon after takeoff, "the bodily mass proceeds toward its destination of its own accord." The daemons eventually will slow the travelers, so they do not crash land.

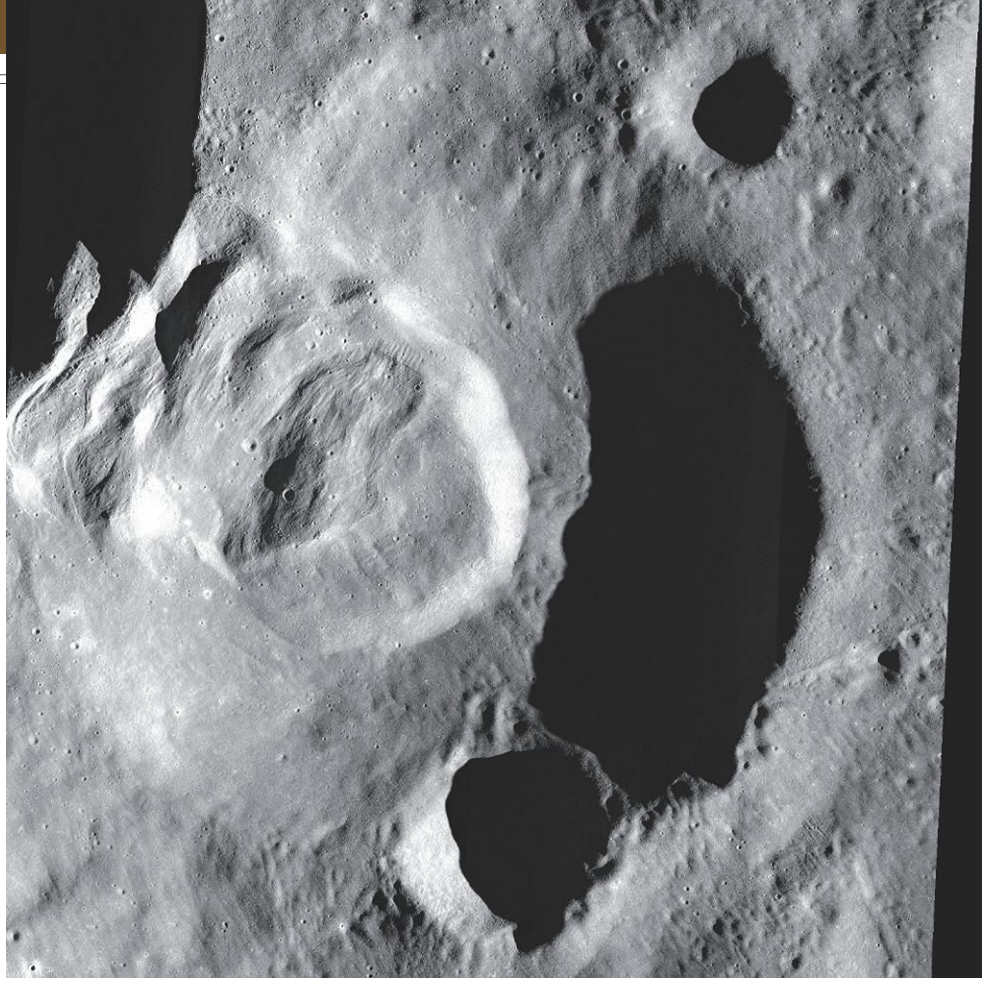
The daemon then discusses the motion of the planets as seen from the Moon and describes Levanian flora and fauna. Each lunar day equals two weeks on Earth, and each night another 14 Earth days. The daemon explains that life on the Moon is distinct for the Subvolvans who constantly face Volva (the revolving Earth), and the Privolvans on the Moon's far hemisphere, which never faces Earth. The daemon reports that for the Subvolvans, Volva remains in place as if "attached to the heavens with a nail" and will present an appearance of alternating light and dark patches — rather like the Moon to us — though 15 times bigger. As Earth rotates, the Subvolvans admire views of its shifting land masses. The planet also will wax and wane in the sky.

Because of their vast size, the Moon dwellers' lives are brief. Plants typically have a lifespan of only one day (or an earthly month). Most inhabitants resemble massive serpents with thick,

LEFT: The title page of *In Somnium Astronomicum* indicates the book was published posthumously in 1634 by Ludwig Kepler, Johannes Kepler's son. LIBRARY OF CONGRESS, RARE BOOK AND SPECIAL COLLECTIONS DIVISION

RIGHT: Within his tale of two humans brought to the Moon by a daemon, Kepler illustrated his scientific ideas on the dynamics of the Earth-Moon system, including lunar phases and eclipses. LIBRARY OF CONGRESS, RARE BOOK AND SPECIAL COLLECTIONS DIVISION





"Kepler thought about what life would be like on the Moon and what kind of life forms it would take, making it the first proper alien tale — he didn't expect just to find other humanoids in space."

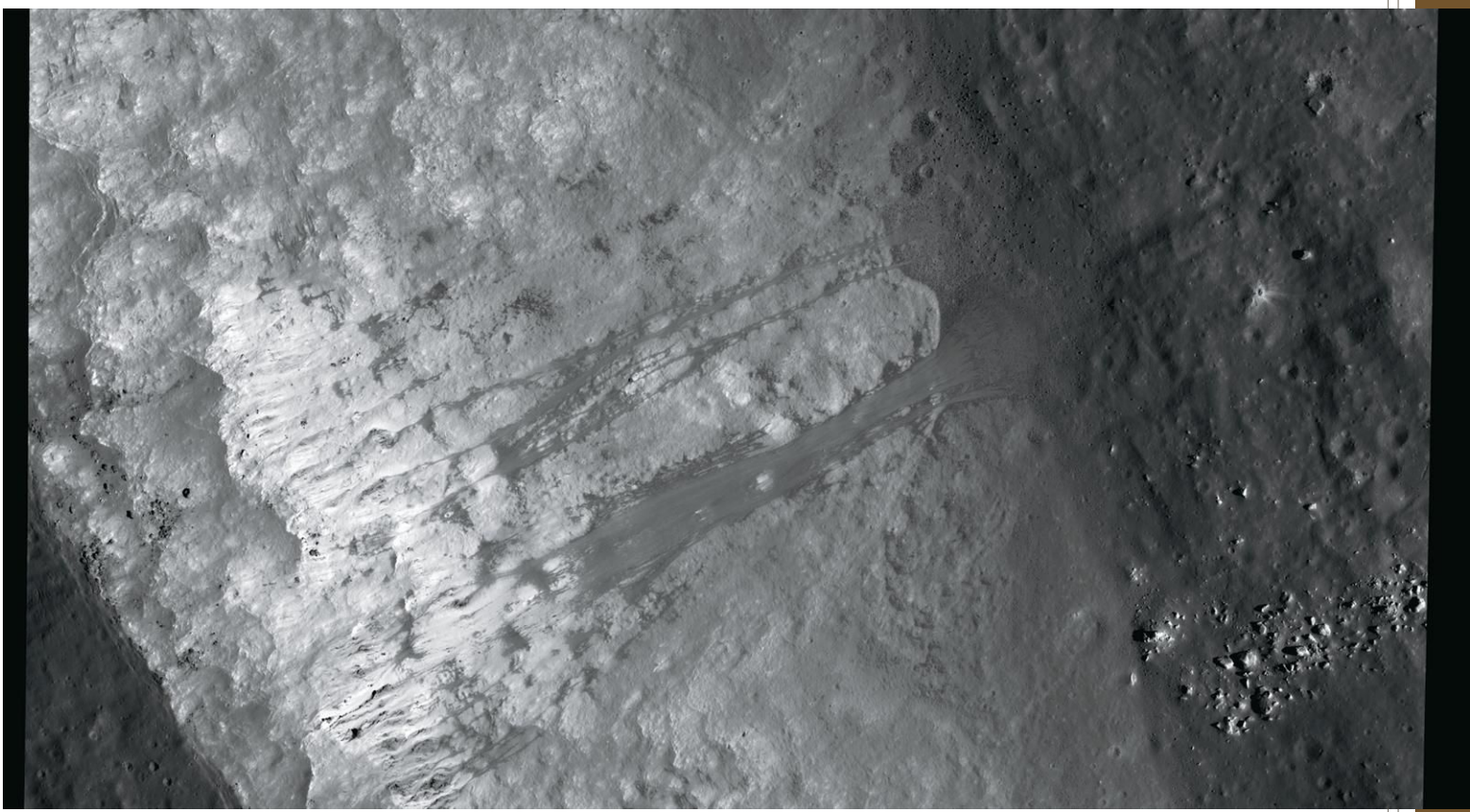
"spongy and porous" hides to survive extremes of heat and cold. They shed these husks when they become Sun-scorched. They roam in crowds, over mountains and plains, and scatter shells that crack open and "beget living creatures." Often, for survival, they escape the heat and cold in underground caves and oceans. After a further disquisition on the Levanians' view of Earth and the heavenly bodies, the dreamer awakes with his bedsheets over his head, resembling Duracotus and Fiolxhilde awaiting their possible journey to Levania.

Beyond the book

The story was slender, about 30 pages, but to explain the underlying science, Kepler added 223 lengthy and often entertaining notes. The architect Giovanni de Galliano Pieroni wrote to his friend Galileo that Kepler's posthumous work was "strange and bizarre." Adam Roberts, a professor at the University of London and author of *The History of Science Fiction* (Palgrave Macmillan, 2005), proposes that this is just what makes *Somnium* "the first proper work of science fiction." He argues that Kepler's juxtaposition of the "grotesque" with "sober science" embodied the dynamic from which all science fiction emanates.

Roberts notes that while there had been previous fanciful accounts of voyages to the Moon, in all these tales, the "aliens" encountered on other worlds had always been other humans. Kepler recognized that would not do. "Kepler thought about what life would be like on the Moon and what kind of life forms it would take, making it the first proper alien tale — he didn't expect just to find other humanoids in space."

While the text was playful, Kepler's intermixing of magic and autobiography conceivably endangered his mother's life. The narrator appeared a stand-in for Kepler — he had apprenticed to Brahe, and Kepler's mother, like Fiolxhilde, concocted herbal potions. When Kepler first learned that his mother was accused of witchcraft in 1615 (but not yet arrested), he was convinced that his enemies had read a version of *Somnium* that he had circulated in 1611. He claimed in his notes at the end of



ALL ABOVE: Today, the surface of our satellite has been photographed and mapped in exquisite detail. These images, taken by the Lunar Reconnaissance Orbiter, show just a few of the otherworldly landscapes found on the Moon. From upper left to right: bright ejecta thrown out following an impact, Montes Recti massifs near Mare Imbrium, the slumped walls of Klute Crater, and a landslide down one wall of Kepler Crater (named for Johannes Kepler).
NASA/GSFC/ARIZONA STATE UNIVERSITY

Somnium that unscrupulous readers began to "chatter" and spread "malicious gossip."

When first charged, Katharina Kepler sued her accusers for slander, but in 1620, after further accusations, she was imprisoned and threatened with torture. Her prosecutor, Lutherus Einhorn, had successfully condemned eight other women to death by burning. Kepler wrote numerous petitions and traveled long distances to aid her defense. Though he successfully exonerated her in 1621, she never recovered from the trauma, dying a few months later.

Of the connection between *Somnium* and Katharina's trial, Kepler biographer James Voelkel offers, "I think he felt guilty about the situation. I'm not convinced there was evidence that the manuscript actually had been leaked. But he'd written a book in which his mother figure was a witch and then his own mother was put on trial. He felt some responsibility."

After the trial, Kepler was eager to publish *Somnium* and set the record straight, but it was not to be. Work, political turmoil, and moves all delayed the project. Finally, in 1630, he arranged for *Somnium* to be typeset and left home on a trip, seeking back interest owed him. While traveling, he fell ill and died. Kepler's family, in dire financial straits, finally published *Somnium* in 1634, after his death.

Fanciful accounts of Moon voyages became popular in decades to follow. English author Francis Godwin's *The Man in the Moone* (1638) depicts a hero harnessing a flock of swans to carry him off the planet — taking advantage of the swans' yearly migration from Earth to the Moon. In 1657, author Cyrano de Bergerac relied on fireworks to send a traveler to the Moon. Two centuries later, Jules Verne's Moon-bound voyagers blast off from a great cannon in Florida. In *The First Men in the Moon* (1901), H.G. Wells' travelers rely on antigravity to float skyward and crash-land on a lunar terrain of monstrous flora similar to that of *Somnium*.

Were Kepler around today, he would relish the advances in lunar geography made since he penned *Somnium*. He might also be amused that 21st-century advocates of Moon settlement hope to make his crater and cave dwellers a reality, with plans for subsurface lunar homes as refuges from heat, cold, and radiation. Underground lava tubes that NASA's Lunar Reconnaissance Orbiter recently confirmed would be promising habitats for Kepler's fictional creations. Had he learned of them in his lifetime, he might have even penned a sequel — or more likely, added a long, entertaining endnote.

Fred Nadis *is the author of* Star Settlers: The Billionaires, Geniuses, and Crazed Visionaries Out to Conquer the Universe *(Pegasus Books, 2020).*

The rebirth

Yerkes Observatory was completed in 1897 and stands to this day in Williams Bay, Wisconsin.

# of Yerkes

After the 130-year-old observatory went dark, a nonprofit organization and local community helped it see the light again.

STORY AND IMAGES BY SAMANTHA HILL

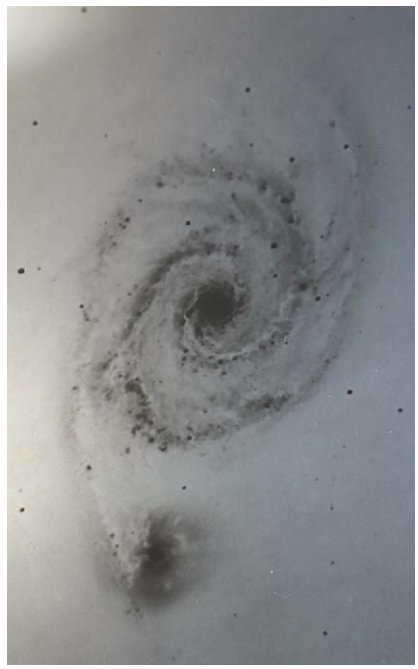
THE TOWN OF WILLIAMS BAY, WISCONSIN, is much like any other small city on a lake, with an offering of tourist shops and a busy beach. But just a short drive past the activity brings you to Yerkes Observatory. Behind an opening in the trees stands a sprawling, grand estate with a well-manicured lawn and a large, ornate building sitting proudly atop a small hill overlooking the water.

Regardless of its intricate facade, Yerkes Observatory fell out of favor with its previous owner, the University of Chicago, because of its expensive upkeep and less-than-ideal location. The school eventually closed the observatory in October 2018.

However, the community of Williams Bay was adamant that the property would not become another shopping center or generic apartment building. Instead, the Yerkes Future Foundation was born that same year. Thanks to money raised by various donors and locals, the historic observatory opened its doors to the public once more in 2022. The foundation now uses this historic site as a bridge to future scientific exploration.

Creating a legacy

In 1892, prominent astronomer George Ellery Hale started the astronomy department at the newly established University of Chicago. Around the same time, the school came into possession of the largest refracting telescope in the world, with a 40-inch lens, following the display of the telescope's mounting and tube at the 1893 World's Fair in Chicago. Building on these two accomplishments, the school set about establishing an observatory.



This glass plate displaying the Whirlpool Galaxy, or M51, was taken in 1902 and is still a part of the University of Chicago's archives.

Yerkes Observatory was funded by Charles Yerkes, the "most hated man in Chicago." Yerkes, the key financier of streetcar systems in Chicago at the turn of the century, was notorious for kicking people out of their homes,

TOP: A collection of early desktop computers is among the eclectic collection of historic items in the observatory.

MIDDLE: This wicked-looking carved face represents the building's namesake, Charles Yerkes, "the most hated man in Chicago."

BOTTOM: Another example of the vast assortment of equipment at Yerkes, this dewar is a vacuum container designed to transport liquid helium at extremely low temperatures.

taking bribes, and having multiple affairs, among many other loathsome behaviors. In an attempt to combat his notorious reputation, he donated the funds to build the observatory, as long as it was constructed within 100 miles (160 kilometers) of Chicago. And although he only visited the observatory once when it opened in 1897, and left the Midwest to distance himself from his misdeeds, his name lives on today. His visage can also be found around the building in the form of decoratively carved stonework. Other sculptural faces bear the likeness of the university's then-president, William Harper, as well as the unflattering and embellished features of John D. Rockefeller.

Hale's influence over the years allowed the university's astronomy department to grow a robust astrophysics program complete with labs, offices, classrooms, and multiple telescopes. This includes what was the largest telescope in the world for close to a decade, earning it the name the Great Refractor. Hale was not the only big-name astronomer to study at or work for the institution at one time or another. The list also includes Carl Sagan, Subrahmanyan Chandrasekhar, Nancy Grace Roman, Edwin Hubble, and Edward E. Barnard.

In the late 1960s, Yerkes added a 40-inch reflecting telescope (although it is called the 41-inch reflector to avoid mistaking it for the Great Refractor). However, as the years wore on, technology sped ahead and increasing light pollution affected the observatory, so staff focused more on astrophysics. This work included efforts toward NASA's now-retired Stratospheric Observatory for Infrared Astronomy.

By the time the University of Chicago donated the observatory to the Yerkes Future Foundation in 2020, the school had already attempted to sell the property to land developers. However, the community did not want to replace the landmark with commercial property and ultimately the buyer withdrew from the sale. The observatory remained in the school's possession for several more years before it was passed to the foundation.

Time capsule

I visited Yerkes Observatory in the summer of 2024. As I entered the building, its delicate array of stonework featuring mythological creatures, celestial patterns, religious iconography, and other unique designs lining the ceilings gave me the impression of a church or a library. This seems to stand in contrast with the many practical scientific instruments deep within the building.

During one of the tours

CENTER: The observatory boasts three domes. The largest, the 90-foot dome, is home to the Great Refractor.

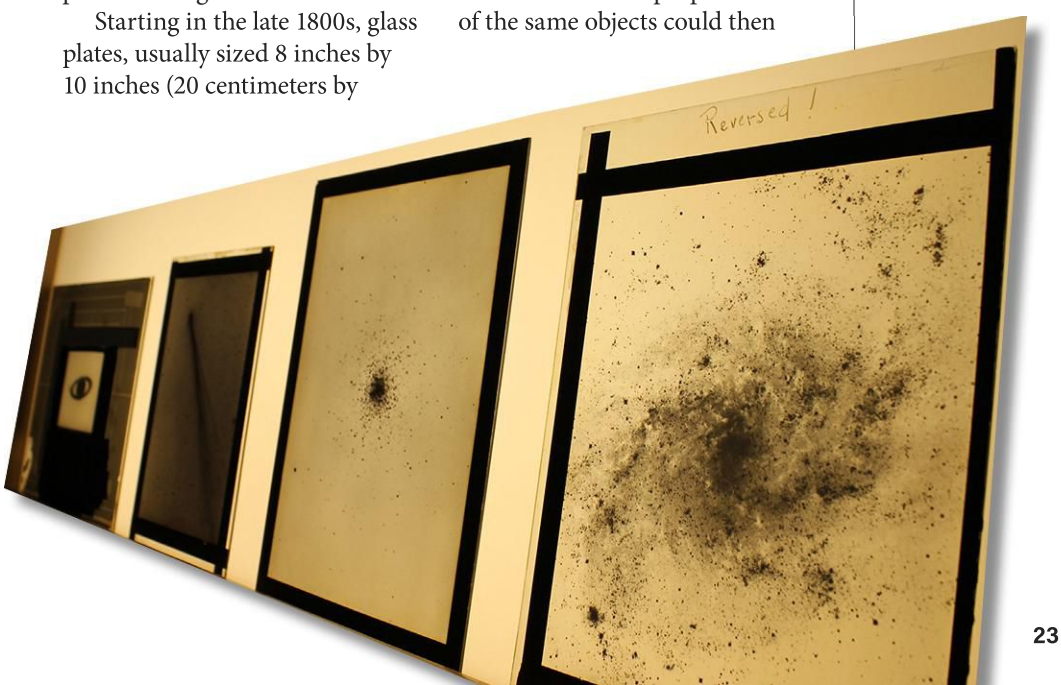
NEAR LEFT: The 41-inch reflector telescope, built in 1968, is still accessed remotely for observations.

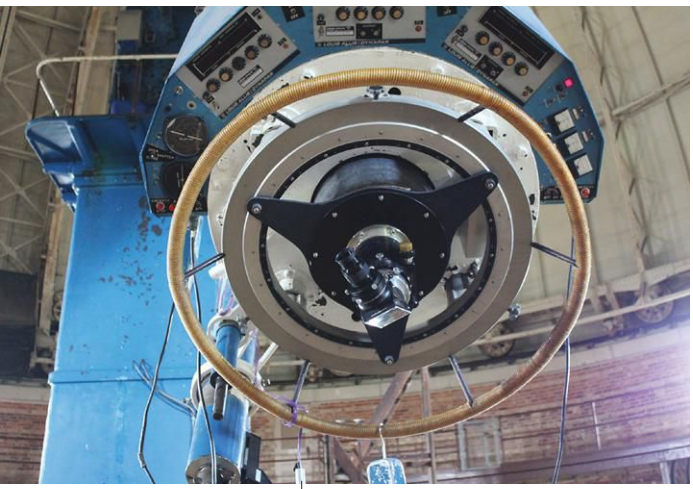
BOTTOM: Displayed here are just a few of the 180,000 glass plates located at Yerkes, including images of Saturn and Halley's Comet.

Starting in the late 1800s, glass plates would be coated in photosensitive chemicals and then exposed to light with a telescope or camera for long periods, capturing faint sky images.

showcasing the more private areas of the observatory (which are open to the public with a fee), it was clear that the Yerkes Foundation wants to faithfully preserve the building's history. This includes a treasure trove of glass plates with priceless images of the cosmos.

Starting in the late 1800s, glass plates, usually sized 8 inches by 10 inches (20 centimeters by 25 centimeters), would be coated in photosensitive chemicals and then exposed to light with a telescope or camera for long periods, capturing faint sky images. This painstaking process was an important aspect of collecting data because multiple plates taken of the same objects could then





ABOVE: The 40-inch refractor's eyepiece can only be reached by using the room's giant mechanical elevator to move the floor up.

RIGHT: The Great Refractor was shown at the Chicago World's Fair in 1893. It was the largest telescope in the world for over a decade.

be compared to show any changes. Yerkes' 180,000-piece collection contains a bevy of objects such as comets, star clusters, and planets.

With the advent of film and then digital processing, glass plates became outmoded. Today, the plates are archival tools, their images still holding information about changes in galaxies and nebulae over time. Through internship programs and volunteers, the Yerkes foundation hopes to eventually digitize the collection.

From the room housing the glass plates, the tour passed through a labyrinth of hallways, stairways, and Hale's elaborate solar-observing tools. We were then taken to the dome of the 41-inch reflector. The telescope still looks similar to how it did when it was installed more than a half-century ago, though it's now operated via computers — the original switchboard located beside it is just for show.

As our group examined the

telescope, we were reminded of how modern telescopes have become much more compact over the years. "Remember the size of this when we go see the other telescope," said Dennis Kois, the Yerkes Foundation executive director, during the tour. The differing lengths between the two, we soon found out, were incomparable.

As the tour group moved to the dome where the Great Refractor is housed, it was clear that this bright blue and white telescope dominated the room. The length of a school bus, it is still functional 130 years later, along with the 120-ton dome overhead.

With such a large telescope comes complications, such as how far the eyepiece is from the ground. The solution to creating a comfortable observing position no matter where the telescope is pointed is a mechanism that turns the floor surrounding the telescope into a giant elevator. I visited during the daytime, but the observatory does offer options for visitors to search the cosmos with the massive telescope at night.

The telescopes are not the only pieces of equipment the observatory maintains. In one room you can find a collection of early desktop computers; in another room in the basement, you'll encounter several large pieces of engineering equipment once used to troubleshoot and fabricate materials like telescope parts. In yet another room is a collection of astronomy books, vintage binoculars, and an old, fat-tire bike used on trips to study the sky in Antarctica.

All these items are kept with the goal of preserving as much as possible of the observatory's past.

Switching hands

The Yerkes Future Foundation has continually worked to update several aspects of the building and the surrounding 50 acres of land. When the foundation first took ownership of the property, the floors were brown from layers of unstripped wax, the walls were tinged with cigarette smoke, and some of the offices had remained untouched for years.

Armed with $23 million in funding, the foundation commenced an effort to revitalize the site and make it usable for visitors. During the two years between purchasing the property and opening the doors to the public, updates included adding solar panels, creating meeting rooms and event spaces, cleaning and organizing 130 years' worth of items, and installing new bathrooms.

Yerkes Head of Science and Education Amanda Bauer says there are many plans for the next 10 years. With the hopes of acquiring another $17 million in donations, the foundation will renovate the Great Refractor, replacing its brick foundation and repainting it, along with other projects like plate digitization and more student programs.

The foundation keeps the community engaged and raises capital with programs like tours of the facility, speakers such as former astronauts, and visitor opportunities to use the telescopes. One of the more unique aspects of their revitalization effort includes incorporating art into the fabric of the observatory. High-contrast photos of broken glass plates line the hallways, while sculptors, painters, and musicians have all completed residency programs that blend the concept of science with art.

Despite the now heavily light-polluted location, Yerkes Observatory retains great value. The historic architecture, the research, and the community programs all bring visitors a great sense of pride. Yerkes has transformed from an observatory without a home to a place for the past, present, and future of astronomy.

TOP: Volunteers are slowly working through the library collection of glass plates to digitize it for the future.

MIDDLE: An image of the total solar eclipse of Jan. 24, 1925, still sits in a window after it was used for imaging in place of a more traditional glass plate.

BOTTOM: The Kuiper Sphere, located in one of the observatory's new display rooms, shows a detailed map of the lunar surface.

Samantha Hill *is editorial assistant of* Astronomy *magazine.*

To learn more about the programs the foundation offers, or if you would like to donate, visit **https://yerkesobservatory.org**.

LIVE LONG AND PROSPER

JWST shows that planets in the early universe didn't form as quickly as theorists thought. BY RICHARD TALCOTT

HOW DID WE GET HERE? Few topics in astronomy intrigue us more than this simple five-word query. Yet the simplicity hides multiple layers of complexity. How did the universe come into existence? How did stars form out of an initial mix of mostly hydrogen and helium gas? How did planets grow in the dusty disks surrounding these stars? And even the answers to these questions can't explain how life and intelligence appeared.

When the James Webb Space Telescope (JWST) began its mission, scientists hoped it would shed light on the key step of planet formation. Mission accomplished. A team of scientists has found convincing evidence that planets in the early days of the cosmos developed over surprisingly long periods.

Before JWST, astronomers mostly studied Milky Way star-forming regions with compositions similar to the Sun. These observations showed that planet-forming disks don't last much longer than 2 million years. That's not much time for dust grains to stick together, coalesce into small rocks, and create massive cores that could grow into planet-sized bodies.

And these findings couldn't account for the majority of the universe's stars, which formed billions of years ago. Dust was scarce because few elements heavier than helium, what astronomers call metals, existed back then. Theorists thought the lack of dust would allow a star's X-ray emission to blow away any disk within a million years or so.

Hubble photographed NGC 346 some two decades ago. This visible-light portrait shows more stars and nebulosity than the JWST image of the same cluster (at right). The Hubble field is slightly smaller than JWST's. NASA, ESA, A. NOTA (STSCI/ESA)

A HUBBLE SHOCK

But the Hubble Space Telescope raised serious questions about this scenario. In 2003, it discovered a planet with 2.5 times the mass of Jupiter circling a neutron star-white dwarf binary in the Milky Way globular cluster M4. These clusters have few metals and yet, somehow, one of them managed to forge a massive planet.

Later that decade, Hubble studied the young star cluster NGC 346 in the Small Magellanic Cloud (SMC), a companion galaxy to the Milky Way located some 200,000 light-years away. Although nearby, the SMC boasts a metallicity only about one-eighth that of the Sun, mimicking what scientists find at much earlier cosmic times. Hubble found some 200 cluster stars up to 30 million years old that seemed to possess planet-forming disks.

JWST PROVES THE POINT

"The Hubble findings were controversial, going against not only empirical evidence in our galaxy but also against the current models," said team leader Guido De Marchi of the European Space Research and Technology Centre in Noordwijk, Netherlands, in a press release. Yet JWST confirmed the Hubble results. The scientists used JWST's Near-Infrared Spectrograph to study 10 Sun-like stars between 20 million and 30 million years old in NGC 346. The spectra — the first of any Sun-like stars in an external galaxy — revealed molecular hydrogen, confirming the existence of circumstellar disks.

JWST's Near-Infrared Camera captured the structure of NGC 346, a metal-poor star cluster in the Small Magellanic Cloud that mimics those in the early universe. Planet-forming disks in the cluster can survive for 30 million years, longer than scientists thought possible. NASA, ESA, CSA, STSCI, A. PAGAN (STSCI)

"With Webb, we have a really strong confirmation of what we saw with Hubble," said De Marchi. "We must rethink how we model planet formation and early evolution in the young universe." The team reported its results in the Dec. 20, 2024, issue of *The Astrophysical Journal*.

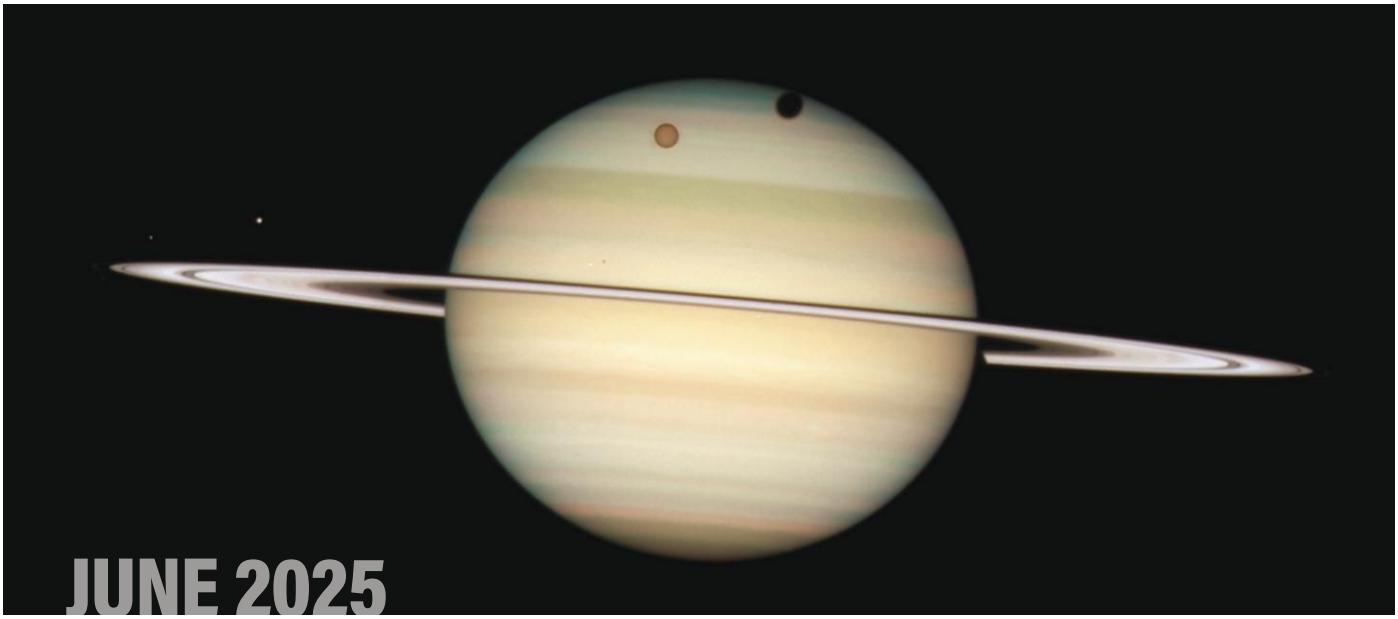
Astronomers now can breathe easier knowing that planets have more time to develop around low-metallicity stars than they do in nearby regions of the Milky Way Galaxy. One possibility the researchers suggest is that stars in metal-poor regions begin life in larger gas clouds that produce bigger disks.

Contributing Editor **Richard Talcott** *wrote about JWST's observations of black holes in distant galaxies in the March issue.*

SKY THIS MONTH

Visible to the naked eye
Visible with binoculars
Visible with a telescope

THE SOLAR SYSTEM'S CHANGING LANDSCAPE AS IT APPEARS IN EARTH'S SKY.
BY MARTIN RATCLIFFE AND ALISTER LING



Titan's shadow appears

The innermost planets straddle nighttime, with Mercury in the evening and the greatest western elongation of Venus in the morning. Jupiter joins Mercury in early twilight for a few evenings, both setting quickly. Distant Mars lingers with Leo after dark, as our own planet hustles along its orbit well ahead of the Red Planet. Saturn is visible in the early hours, as Neptune hangs nearby and is in conjunction with the ringed planet on the 29th. Uranus reappears in the morning sky before dawn.

We'll start in the evening soon after sunset on June 1. You can spot **Jupiter** hanging low in the western sky. It shines at magnitude –1.9 and becomes visible about 20 minutes after sunset, standing 8° high. Each day it becomes harder to see, but is joined June 6 to 9 by Mercury, which is slowly extending its elongation from the Sun.

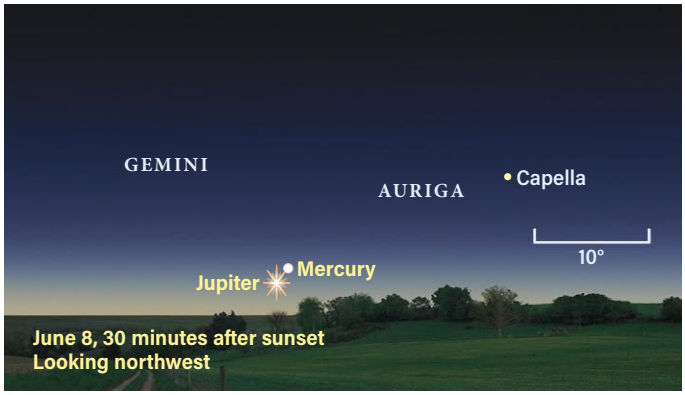
Your first chance to spot **Mercury** is on June 6, when it shines at magnitude –1.5 and stands 3.7° west of Jupiter. The pair of bright planets sits about 3° above the western horizon 30 minutes after sunset. Your observing window is narrow because the planets set together within 25 minutes. Grab a pair of binoculars for the best view in bright twilight, which otherwise makes the two planets challenging to see. Make sure you pick a viewing site with no obstructions. The gap between the planets shrinks to 2.3° by June 7.

June 8 is their formal conjunction, when Mercury stands 2° due north of Jupiter. Jupiter is less than 3° above the horizon half an hour after sunset, while Mercury is 4° high. Mercury has dimmed slightly to magnitude –1.3.

Jupiter is lost from view soon after and heads toward its conjunction with the Sun on the 24th. It'll reappear in the morning sky in late July.

Meanwhile, Mercury continues to climb higher in the evening sky, though it dims as it goes. On the 13th, at magnitude –0.8, it stands 20' from 3rd-magnitude Mebsuta (Epsilon [ε] Geminorum).

Getting low



Jupiter meets Mercury in a conjunction visible for a short time after sunset in early June. ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY

Huge Titan and its shadow transit the disk of Saturn in this 2009 Hubble Space Telescope image. Also visible transiting with its shadow is Mimas, closer to the rings; Dione and Enceladus lie above the rings at left. Such shadow transits of Titan can occur around ring-plane crossings, such as the one in 2009 and earlier this year. NASA, ESA, AND THE HUBBLE HERITAGE TEAM (STSCI/AURA); ACKNOWLEDGMENT: M.H. WONG (STSCI/UC BERKELEY) AND C. GO (PHILIPPINES)

OBSERVING HIGHLIGHT

MERCURY stands 2° due north of **JUPITER** on the evening of June 8.

Binoculars give a fine view of the star nestled next to the planet. Look 45 minutes after sunset, when the planet is 5° high in the west.

By June 24, Mercury has dipped to magnitude 0 and lies in line with Castor and Pollux, both 1st-magnitude stars. It sets about 90 minutes after sunset and stands 5° high at 9:30 P.M. local daylight time from latitudes similar to the U.S.

On the 26th, Mercury sits 3.5° to the left of the slender, two-day-old crescent Moon, and by the 30th it lies within 2.5° of M44, the Beehive star cluster. You'll need binoculars — along with a clear western horizon and good air clarity — to spot the cluster.

— Continued on page 34

RISING MOON | A terrific trio

"OVER HERE!" A triplet of magnificent large craters practically beckons us on the evening of June 3rd. It's the Moon in a classic, highly photogenic profile: First Quarter phase. Just below the middle of the Moon, the northernmost and largest of the three, Ptolemaeus, sports a rugged rim that casts long, spiky shadows onto its relatively smooth floor. There is a noticeable small crater pocking the surface, but can you see the tiny craterlet in the northwest?

Like most large impact features, Ptolemaeus has the associated classic slumped walls and complex central peak — if we could dig them out. Scientists figure that they are buried under massive deposits of ejecta spray from the excavation of the giant Mare Imbrium to the northwest. With the low Sun angle on the 3rd, look for subtle round depressions — telltales of ancient craters hiding under a blanket of dirt. They disappear under the higher Sun of the following nights.

The smaller impact that created Alphonsus to the south produced sharper features and a higher central peak. Come back every hour if you can and note how quickly the spire's shadow retreats under the rising Sun. The unusual ridge bisecting Alphonsus lines up with other linear features that point back to Imbrium as its origin.

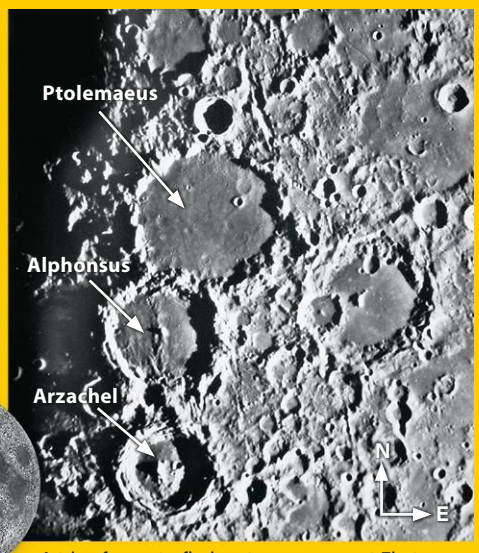
Youngest of the three is Arzachel, farther south. The rim and inner walls have better definition than those of Alphonsus and Ptolemaeus, which were beaten by more millennia of impacts. In comparison, Hipparchus to the northeast suffered an even longer period of bombardment.

There is still more to see on the following nights, as surface composition is revealed under a higher Sun. The floor of Alphonsus sports a handful of darker gray spots. These are deposits of volcanic ash, somewhat gently sprayed out from their central cones. Spectroscopic studies indicate the ash is similar to the lava that welled up to create the large seas.

If you're up past midnight, look just south and west of the trio to see the black triangular shadow of the Straight Wall emerging from the lunar darkness. Otherwise, come back on the 4th.

All features will have shorter shadows when you return July 3rd for another look.

Ptolemaeus, Alphonsus, and Arzachel



A trio of easy-to-find craters appears at First Quarter. The large, well-defined crater at right (east) is Albategnius. *CONSOLIDATED LUNAR ATLAS*/UA/LPL. INSET: NASA/GSFC/ASU

METEOR WATCH | Welcome the clouds

Shining in the night

NO MAJOR METEOR SHOWERS occur in June, but warm summer nights are appealing to lie out under the stars, watch the Milky Way wind through Cygnus and Aquila, and catch those occasional sporadic meteors at random moments.

The occurrence of noctilucent clouds during summer is an additional treat for those observing from northerly latitudes. These iridescent clouds glow long after regular clouds appear dark. Noctilucent clouds lie 10 times higher than cirrus, and are produced when ice crystals form on tiny dust particles in our atmosphere. If you see them, they appear stationary, but time-lapse photography reveals the beautiful ebb and flow of these elusive clouds.

Noctilucent clouds light the night sky above Laboe, Germany. MATTHIAS SÜSSEN/WIKIMEDIA COMMONS (CC BY-SA 4.0, HTTPS://CREATIVECOMMONS.ORG/LICENSES/BY-SA/4.0/)

STAR DOME

HOW TO USE THIS MAP

This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

midnight June 1
11 P.M. June 15
10 P.M. June 30

Planets are shown at midmonth

MAP SYMBOLS

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

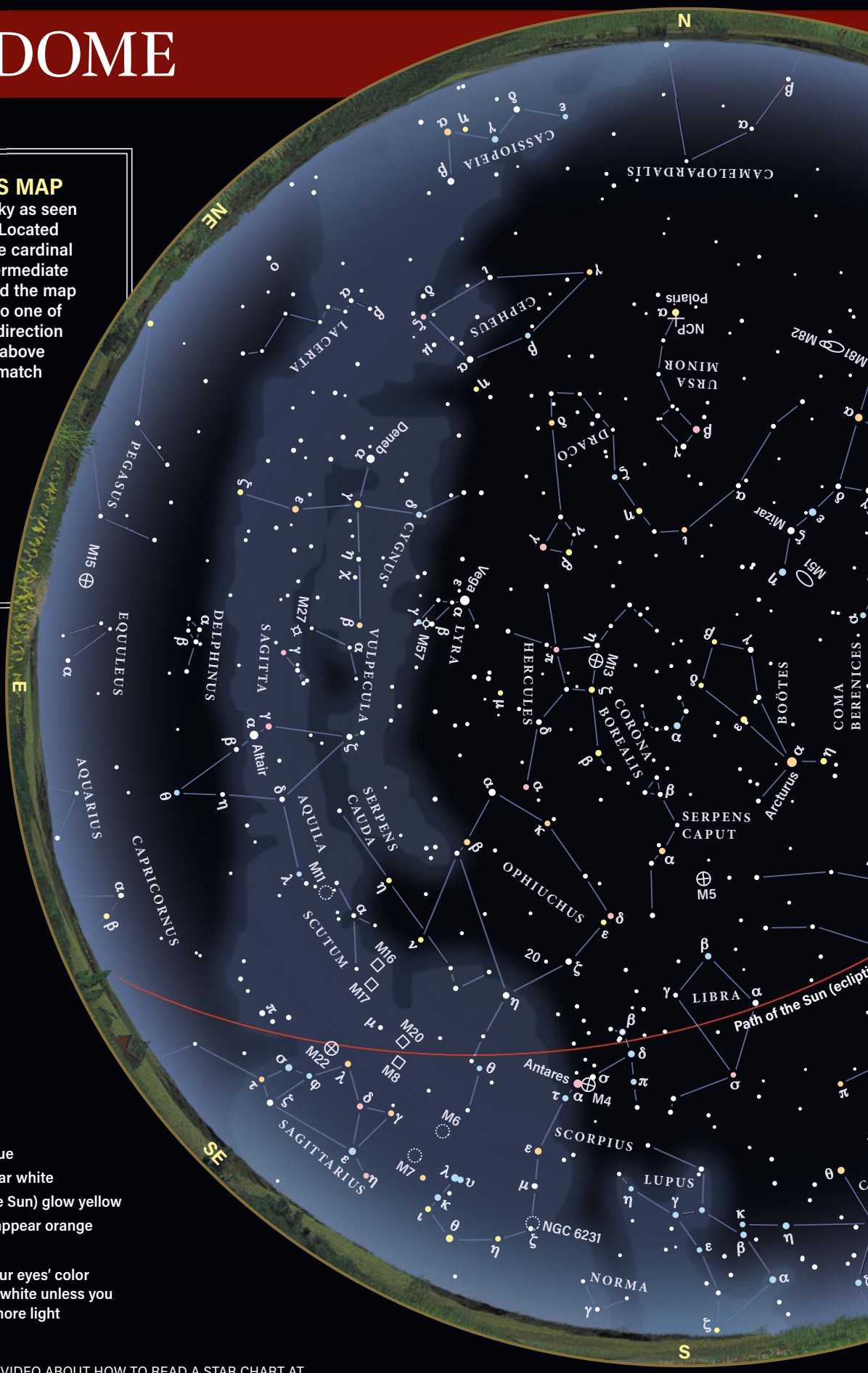
STAR MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light



BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**

JUNE 2025

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

1 The Moon passes 1.4° north of Mars, 6 A.M. EDT

2 First Quarter Moon occurs at 11:41 P.M. EDT

3 Asteroid Pallas is stationary, 5 P.M. EDT

6 The Moon passes 0.5° south of Spica, 11 A.M. EDT

7 The Moon is at apogee (251,999 miles from Earth), 6:44 A.M. EDT

8 Mercury passes 2° north of Jupiter, 4 P.M. EDT

10 The Moon passes 0.3° south of Antares, 7 A.M. EDT

11 Full Moon occurs at 3:44 A.M. EDT

14 The Moon passes 0.1° south of Pluto, 1 P.M. EDT

16 Mars passes 0.8° north of Regulus, midnight EDT

18 Asteroid Vesta is stationary, 3 P.M. EDT

Last Quarter Moon occurs at 3:19 P.M. EDT

The Moon passes 3° north of Saturn, midnight EDT

The Moon passes 2° north of Neptune, midnight EDT

20 Summer solstice occurs at 10:42 P.M. EDT

22 The Moon passes 7° north of Venus, 5 A.M. EDT

Mercury passes 5° south of Pollux, 4 P.M. EDT

The Moon passes 5° north of Uranus, midnight EDT

23 The Moon is at perigee (225,668 miles from Earth), 12:44 A.M. EDT

24 Jupiter is in conjunction with the Sun, 11 A.M. EDT

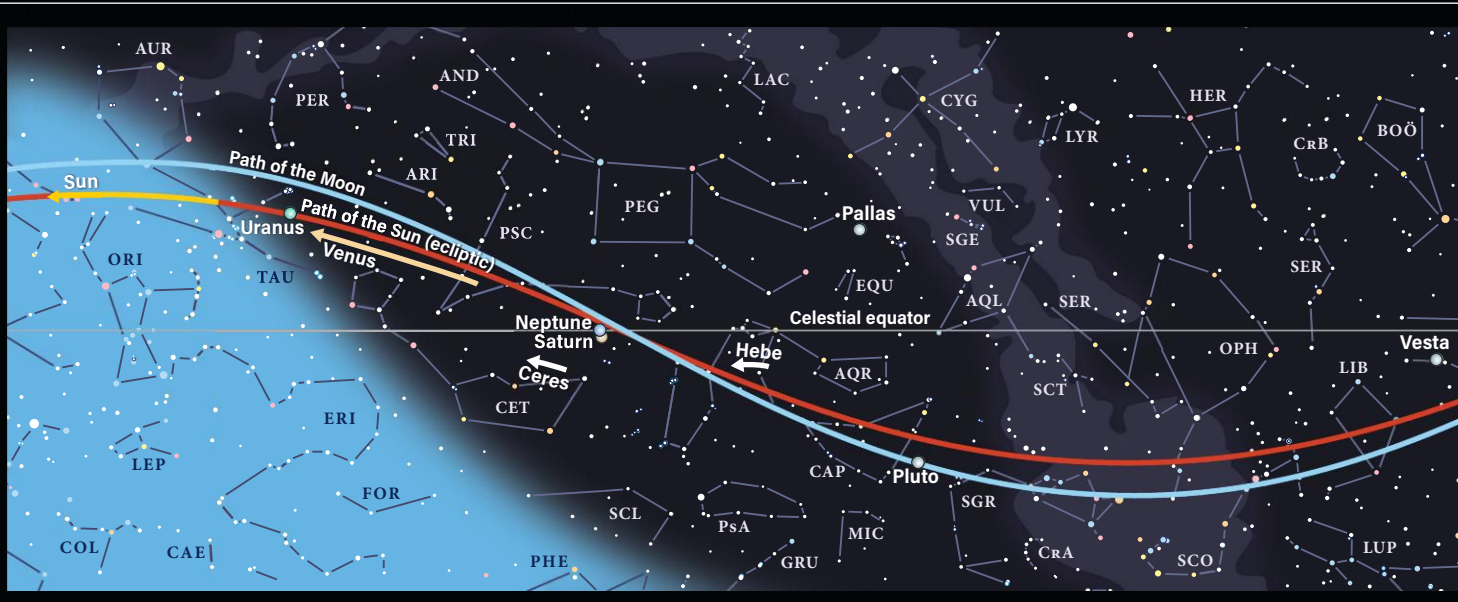
25 New Moon occurs at 6:32 A.M. EDT

27 The Moon passes 3° north of Mercury, 2 A.M. EDT

29 Saturn passes 1.0° south of Neptune, 4 A.M. EDT

The Moon passes 0.2° north of Mars, 9 P.M. EDT

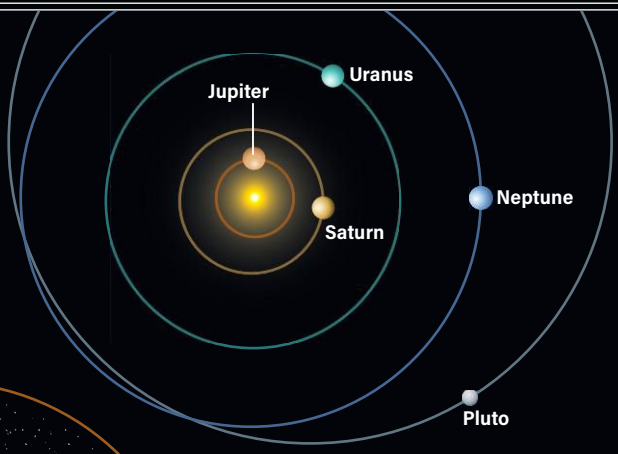
PATHS OF THE PLANETS

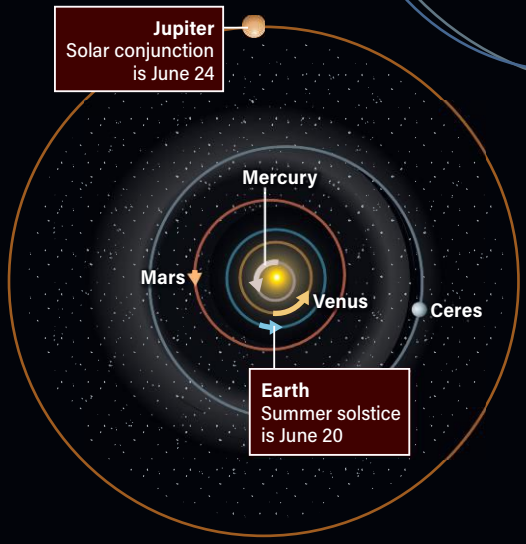


To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

THE PLANETS IN THEIR ORBITS

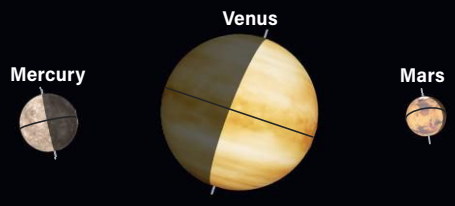
Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at midmonth from high above their orbits.





THE PLANETS IN THE SKY

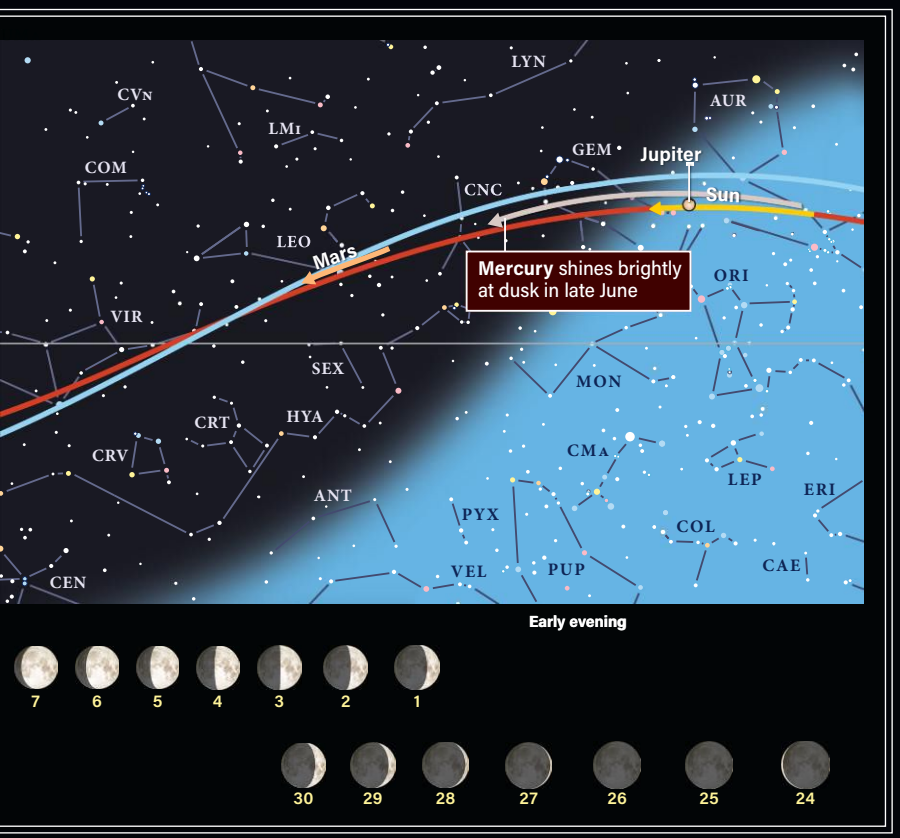
These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets at 0h UT for the dates in the data table at bottom. South is at the top to match the view through a telescope.



PLANETS	MERCURY	VENUS
Date	June 30	June 15
Magnitude	0.3	–4.3
Angular size	7.5"	20.6"
Illumination	48%	57%
Distance (AU) from Earth	0.901	0.811
Distance (AU) from Sun	0.438	0.728
Right ascension (2000.0)	8h24.4m	2h28.3m
Declination (2000.0)	20°04'	11°52'

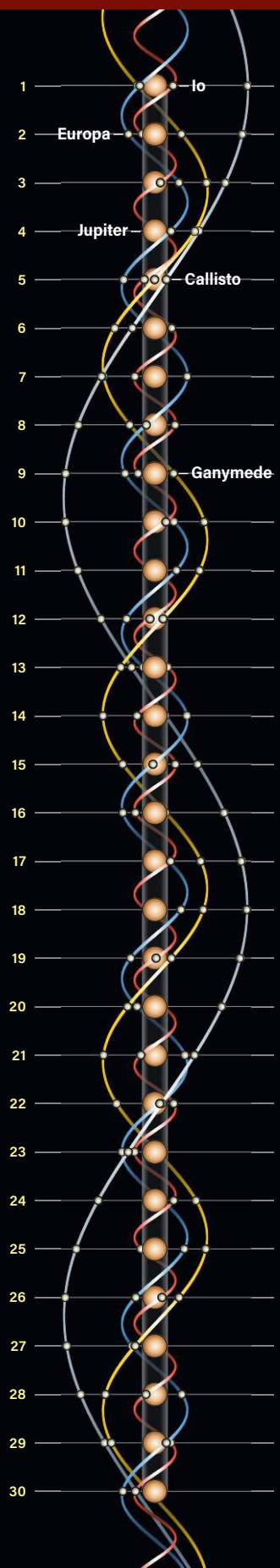
This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

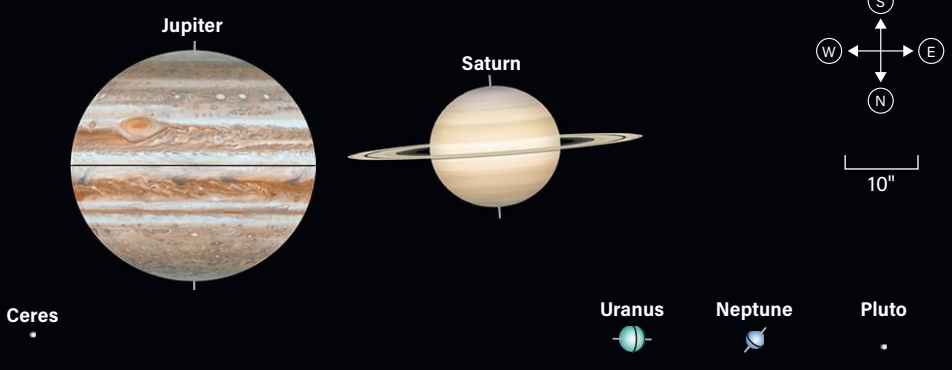
JUNE 2025



JUPITER'S MOONS

Dots display positions of Galilean satellites at 11 P.M. EDT on the date shown. South is at the top to match the view through a telescope.





MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
June 15	June 15	June 1	June 15	June 15	June 15	June 15
1.4	9.2	–1.9	1.0	5.8	7.8	15.2
5.2"	0.4"	32.4"	17.2"	3.4"	2.3"	0.1"
92%	97%	100%	100%	100%	100%	100%
1.807	3.056	6.094	9.653	20.439	30.013	34.493
1.649	2.977	5.134	9.580	19.525	29.890	35.284
10h03.7m	0h46.2m	5h49.8m	0h06.8m	3h45.4m	0h08.4m	20h25.2m
13°13'	–6°15'	23°14'	–1°37'	19°38'	–0°31'	–23°02'

 — *Continued from page 29*

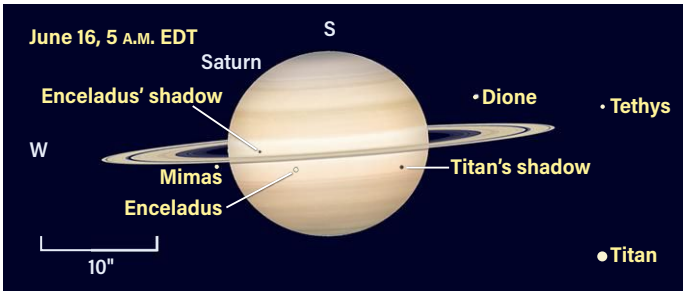
WHEN TO VIEW THE PLANETS

EVENING SKY
Mercury (west)
Mars (west)
Jupiter (west)

MIDNIGHT
Mars (west)

MORNING SKY
Venus (east)
Saturn (southeast)
Uranus (east)
Neptune (southeast)

Special event



Thanks to our current viewing angle, Titan's shadow transits Saturn this month, concurrent with a transit of Enceladus and its shadow. Although the latter two are shown here, they will likely be invisible against the bright disk.

It's worth following Mercury with a telescope throughout June. Its disk is tiny, spanning a mere 5" on the 6th, when it lies far beyond the Sun. As the month progresses, Mercury moves in its orbit, and by the end of June its disk has grown to 8" across. During the same period, we see the phase change from a nearly full, 92-percent-lit disk on June 7 to 50 percent lit on the 28th. By June 30, it is a fat crescent, 46 percent lit.

Mars and a waxing crescent Moon shine 8° apart on June 1 in the constellation Leo the Lion. They're visible high in the western sky as dusk falls. Mars glows at magnitude 1.2 and dims to magnitude 1.4 during June as it moves across Leo. It has a conjunction with Regulus, Leo's brightest star, on the 16th, standing 48' due north of the star. Check out the lovely color contrast of these two objects: the orange glow of Mars and the bluish-white hue of Regulus.

Mars continues across southern Leo in the latter half of the month and the Moon rejoins on the 29th, this time less than a degree away. Once the Moon is out of the way on the 30th, look for the galaxy pairing of M95 and M96, standing 2.5° northeast of the Red Planet.

Features on the surface of Mars are difficult to see with the planet standing more than 1.7 astronomical units from Earth. (One astronomical unit, or AU, is the average Earth-Sun distance of 93 million miles.) Its disk spans 5" at the end of June.

It's 2:30 A.M. local daylight time on June 1 before the next planet arrives on the nighttime scene, when **Saturn** rises in the east. At the onset of morning twilight early in the month, it's about 20° high and within reach for viewing, not long after the ring-plane crossing earlier in the year. Its elevation increases throughout the month, exceeding 35° altitude in the southeast in morning twilight by June 30.

Now — and for the next 13 years — the southern face of Saturn's rings are on view. The current ring tilt is less than 4°, offering a clear view of the entire disk of the planet. It spans 17", so check out any dark belts and look for white spots, which indicate upwelling storm clouds and are very rare.

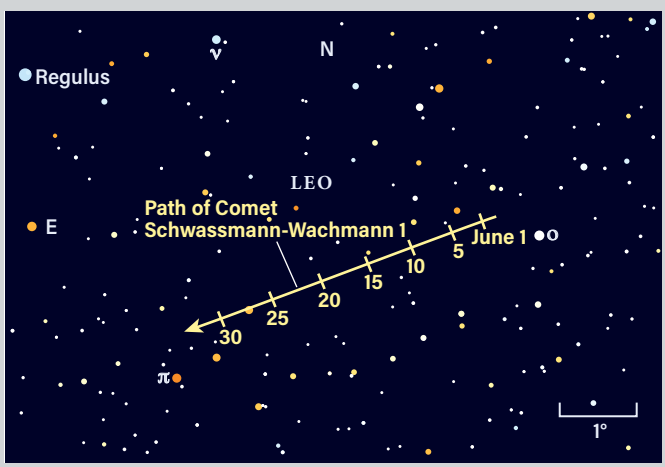
Watch for a special event on the morning of June 16, when a transit of Titan's shadow begins at 4:11 A.M. EDT. The ringed planet is less than 10° high in the Mountain time zone, with the best views for those in the Eastern time zone. As Saturn rises higher across the Midwest, the dark shadow of the large moon progresses across the disk. It reaches the central meridian around 5 A.M. MDT, not long before sunrise. Such shadow transits are frequent when we're close to ring-plane crossings (which occurred in

COMET SEARCH | Troll deep and hope

COMETS THAT CLIMB to binocular brightness too fast to be highlighted in this column are discovered on average once a year. Five years ago, there were four surprises, one of them the marvelous C/2020 F3 (NEOWISE). Clearly June is too early to be announcing a comet of the year.

Comets emit light from fluorescing gas, notably the long blue tail streaming outward and the eerie green glow surrounding the coma. But most often, it's the liberated dust scattering sunlight that contributes the most to a comet's brightness. Comet 29P/Schwassmann-Wachmann, beyond the orbit of Jupiter, has puffed out clouds of dust at irregular intervals for decades without breaking apart like most others. If we're lucky, it will be glowing at 11th magnitude this month, sporting a 3' to 5' halo and bright central false nucleus.

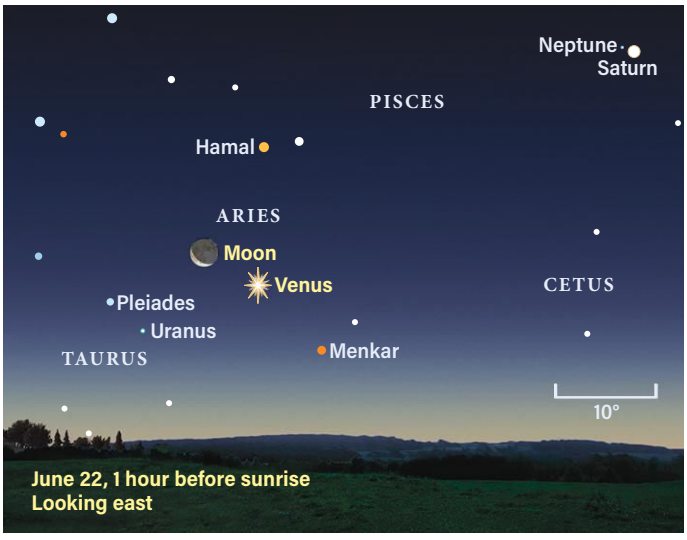
Comet 29P/Schwassmann-Wachmann



This month, we'll continue to track faint 29P, also known as Comet Schwassmann-Wachmann 1 — and hope for an unexpected visitor. Keep an eye on www.Astronomy.com for an alert.

Schwassmann-Wachmann 1 is best during June's last two weeks, when the Moon isn't interfering. Target it as night falls before it sinks too low. Drop south of Regulus to Pi (π) Leonis and nudge your scope westward to a 6th-magnitude field star as guidepost. To prepare yourself, try galaxy NGC 3049 (magnitude 12.5) at powers above 150x.

Picture perfect



The predawn sky is chock-full of sights to see in late June. Note that Neptune and Uranus require binoculars or a telescope to spot.

March), so expect more in the coming months.

Neptune lies 20 AU (about 1.9 billion miles) beyond Saturn. On the 29th, it is exactly 1° due north of 1st-magnitude Saturn. It's a great time to find the bluish disk of this distant world. Neptune shines at magnitude 7.8, within reach of a pair of binoculars; Neptune sits to the upper left of Saturn. A few other stars of similar magnitude lie in the region, but all in other directions, so Neptune should be easy to locate.

Through a telescope, Neptune is a challenge, spanning 2", yet is a view worth beholding as you contemplate this distant world orbiting at the edge of the plane shared by the planets. If you could view the Sun from Neptune, it would appear 30 times smaller than it does from Earth, or just 1' across. Yet it would still attain a brilliance 500 times that of the Full Moon.

Venus reaches greatest western elongation 46° from the Sun at midnight on May 31. The brilliant planet (magnitude –4.4) rises at 3:30 A.M. local daylight time on June 1 and begins the month located in Pisces the Fish. It traverses Aries from the 10th to the 28th, entering Taurus the Bull just less than 10° southwest of M45, the Pleiades star cluster.

There are two ways to appreciate Venus in the predawn sky: with the naked eye or with a telescope. Later in the month, you can see Venus with the naked eye, along with the Pleiades and Hyades star clusters and the bright, orange-hued star Aldebaran. From June 22 to 24, the crescent Moon joins the scene, adding to the spectacle — perfect for a summer morning photograph. The Moon stands 7° north of Venus on the 22nd.

Through a telescope, Venus reveals additional features this month. On June 1, it shows a 24"-wide, half-illuminated disk, dubbed *dichotomy*. Do you see it as 50 percent lit? The Schröter effect is in play, where individual perception and light variations in the venusian atmosphere can affect the appearance of the disk, causing dichotomy to occur a few days later than predicted during morning apparitions.

The disk of Venus shrinks to 18" by the end of June, now exhibiting a gibbous phase that is 64 percent lit. The planet's increasing distance from Earth has diminished its brilliance slightly, to magnitude –4.2.

Uranus is an easy binocular object for a short period before twilight interferes. The best time to view the planet is June 30, when it stands 5° northeast of Venus. The ice giant's visibility improves in July.

The summer solstice, when the Sun appears at its northernmost declination for the year, occurs June 20 at 10:42 P.M. EDT.

Martin Ratcliffe *is a planetarium professional with Evans & Sutherland and enjoys observing from Salt Lake City.* **Alister Ling**, *who lives in Edmonton, Alberta, is a longtime watcher of the skies.*

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LOCATING ASTEROIDS
Five-minute asteroid gazing

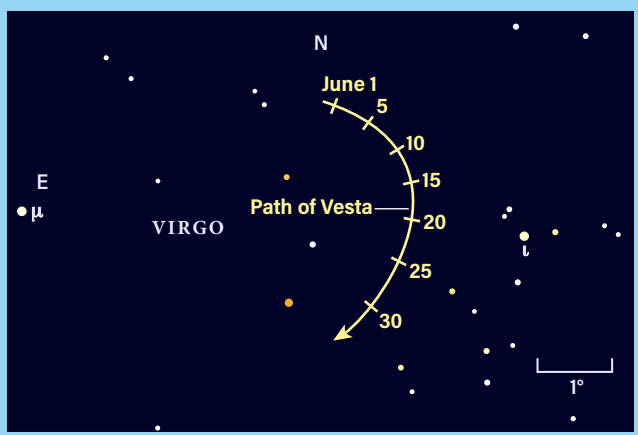
GET A KICK out of following an asteroid from your city balcony or backyard with only five minutes of dark adapting. The offer ends this month and isn't back for a full year. The second-largest object in the main belt, 4 Vesta shines at magnitude 6.1 but slowly fades to 6.7 by the end of June, as faster-orbiting Earth leaves it behind.

Slowly scan your binoculars 15° northeast (to the upper left) of blue-white Spica. Find the outline of a tilted bell dotted by 5th- to 6th-magnitude stars, just fitting in the field of view at 7x. Place those dots in a logbook, along with the next four brightest, in the middle — one will be Vesta. Return every three nights or so to see it has shifted. The Moon passes by on the 6th and 7th, but more than 10° to the south. With Vesta so bright, this shouldn't be an issue.

Vesta was discovered in 1807 by Heinrich Olbers, six years after Ceres. Its high reflectivity (albedo) of 0.38 lets it outshine the dwarf planet despite being half its size.

The 8th offers an excellent chance to watch a different asteroid move in less than two hours. Passing only a few arcminutes north of Regulus and its 8th-magnitude companion, 29 Amphitrite (magnitude 11.2) starts the night creating a crooked line and ends it as part of a tight triangle.

Follow the curve



Vesta takes a compact, curving path in Virgo this month, bracketed by Mu and Iota Virginis.

EXPLORE THE MOON'S MOTIO

Earth's companion is more than just a pretty face. It has allowed astronomers to define lunar cycles, navigate without technology, and understand celestial movements.

BY RAYMOND SHUBINSKI

HUMANITY'S NEED to track the Moon's changing phases and motions is ancient. Mammoth hunters used the Moon as a timekeeper, carving crescent-shaped notches into bone and tusk. Sumerian astronomers recorded the Moon's motion on clay tablets more than 3,000 years ago.

But as reliable and trustworthy as the Moon may seem, its dance around Earth and the Sun is also full of nuances and variations — expressions of the complexity and beauty of the laws of physics. Observing these subtle movements and unlocking their secrets was key to understanding our place in the cosmos.

Today, appreciating the many motions of the Moon connects us to one of the driving forces of science across the centuries, one that has led us from the pseudoscience of astrology to the complexities of landing on the Moon.

All the "Moonths"

As Earth orbits the Sun, the Sun appears from our perspective to follow an imaginary line called the ecliptic that circles the celestial sphere. The Moon and planets all travel near the ecliptic, within 6° of it. The 12 traditional constellations that lie along this line are called the zodiac.

While the Sun takes 365¼ days to complete one trip around the ecliptic and return to the same position, the Moon zips around this imaginary circle in just under 30 days.

It's a delight to watch a thin crescent rise in the west shortly after sunset. Our natural satellite then progresses through its phases until it rises as a Full Moon in the east, opposite the setting Sun in the west. The Moon continues on its journey until it rejoins the Sun as a New Moon. This period of time, from one New Moon to the next, is called a synodic month and takes 29 days, 12 hours, 44 minutes, and 2.8 seconds to complete.

NS

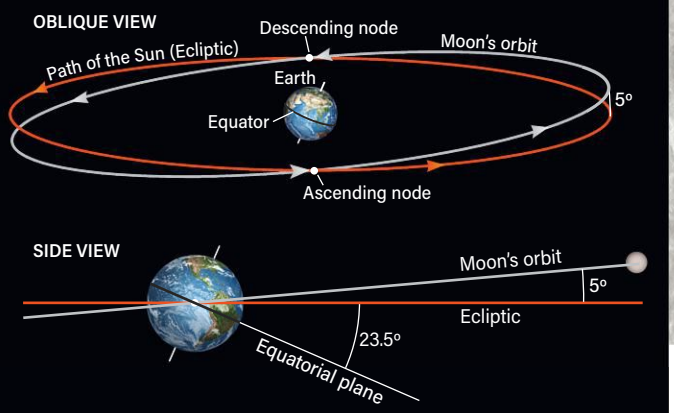
The Sun-Earth-Moon system are constantly at play, but Earth and its lunar satellite are a bit more intimate — with a center of mass, or barycenter, 2,900 miles (4,600 km) from Earth's center. *ASTRONOMY:* ROEN KELLY

This synodic lunar cycle was used for a millennium to make our calendars.

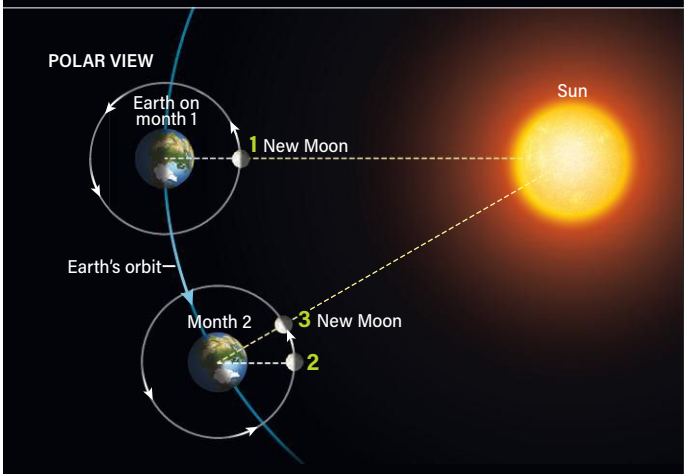
There are other ways to measure the Moon's cycle. The Moon appears to move eastward approximately 13° a day along the ecliptic, leading to the next defined lunar cycle: a sidereal month. It lasts 27 days, 7 hours, 43 minutes, and 11.5 seconds, which is the time it takes our satellite to make one complete orbit around Earth. From our perspective, a sidereal month is measured when the Moon completes one circuit around the ecliptic, returning to the same point from where it began in reference to the fixed stars.

A draconic month (also called a nodal month) is yet another way to measure the Moon's motion. Ancient observers realized that the Moon does not track the ecliptic perfectly. This is because the Moon's orbit is inclined 5.1° to the ecliptic, causing it to appear above or below the plane. There are two exceptions per month when the Moon crosses the ecliptic, at points called lunar nodes. An ascending node occurs when the Moon crosses the ecliptic from south to north, and a descending node occurs when the Moon moves across the ecliptic from north to south. This cyclical motion requires 27 days, 5 hours, 5 minutes, and

THREE "MOONTHS" TO KNOW



DRACONIC CYCLE: It takes 27 days, 5 hours, 5 minutes, and 36 seconds for the Moon to orbit Earth through the same node.

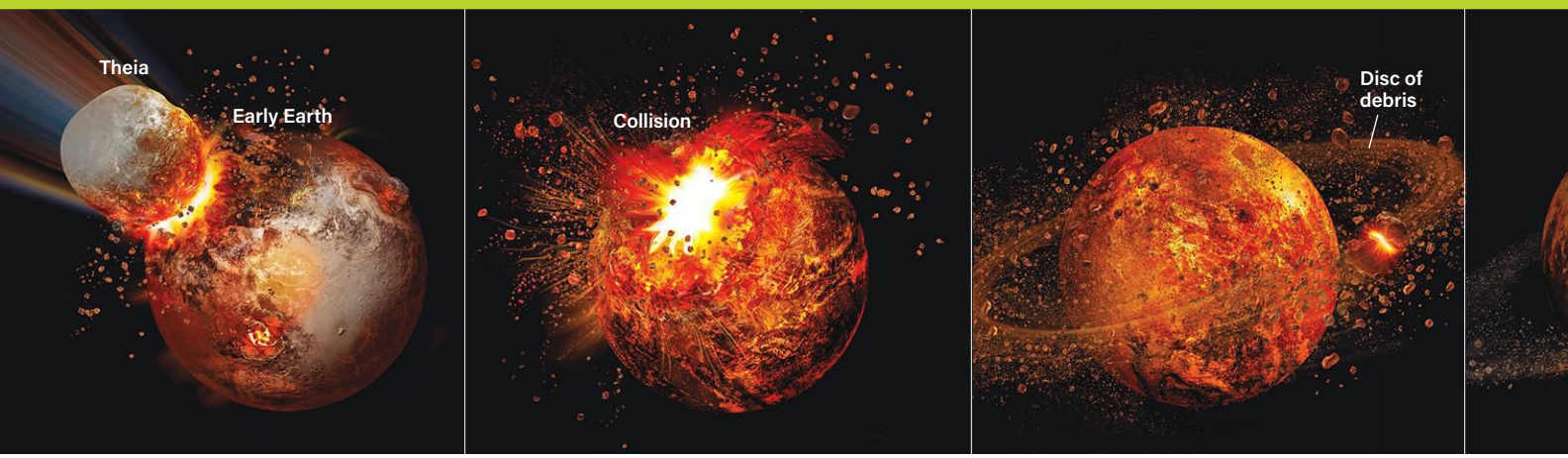


SIDEREAL LUNAR CYCLE: The time it takes the Moon to complete an orbit (360°) around Earth is 27 days, 7 hours, 43 minutes, and 11.5 seconds (steps 1–2 above).

SYNODIC LUNAR CYCLE: The time it takes the Moon to cycle through the moon phases from one New Moon to the next New Moon is 29 days, 12 hours, 44 minutes, and 2.8 seconds (steps 1–3 above).

ASTRONOMY: ROEN KELLY AFTER SUBRATA CHAKRABORTY AND BRITANNICA KIDS

CREATING THE MOON THROUGH A GIANT IMPACT



The Giant Impact Hypothesis states that a Mars-sized body, called Theia, crashed into a young Earth about 4.5 billion years ago. All the debris in Earth's orbit coalesced to eventually form the Moon. *ASTRONOMY:* ROEN KELLY

36 seconds, slightly shorter than a sidereal month.

Solar and lunar eclipses can only happen when the Moon crosses these nodes. Some cultures — for example, in Chinese mythology — believed a dragon lurked along the nodes, waiting to swallow the Sun or the Moon, hence the name *draconic*.

These are only a few ways to differentiate lunar months, but the Moon provides more ways to measure time and seasons.

A cosmic ballet

The Moon always shows us the same face because its rotation and orbit are tidally locked. In the early solar system, a Mars-sized object, called Theia, collided with the infant Earth to eventually form the Moon. (This is known as the Giant Impact Hypothesis.) As the Moon coalesced, Earth's gravity slowed the lunar spin until its rotation matched its orbit around Earth, thus denying us a view of what is now the far-side. But even this motion has a twist. Because the Moon's orbital motion is elliptical it appears to rock back and forth like a pendulum, a motion called libration. This wobble allows us to see slightly more than half the lunar surface. The changes this apparent motion causes are best observed with a telescope.

The Moon's motion along the ecliptic provides an interesting counterpoint to the Sun's annual progress. Each year, as Earth completes a single orbit around the Sun, the Moon orbits our globe about 13 times. From our viewpoint, it's easy to imagine the Moon tracing out the Sun's path along the ecliptic. For example, the Sun slides into the constellation Sagittarius on the winter solstice. A Full Moon near the winter solstice, known as the Long Night Moon, will appear directly across the sky in Gemini. In six months, this is where the Sun will appear. And as the Sun sets in the southwest on the winter solstice, the Moon will rise in the northeast where the Sun rises on the summer solstice. This pas de deux between the Sun and the Moon continues throughout the year and is fascinating to watch.

Navigation advances technology

Intellectual curiosity is not the only force that has pushed us to refine our understanding of the world. In the 15th and 16th centuries, navigation techniques became paramount to Europeans like Amerigo Vespucci who explored the Americas and searched for wealth to exploit.

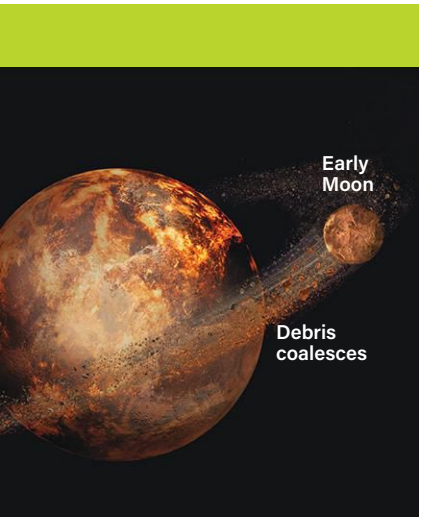
The problem was knowing your exact position on the globe. It had long been known that the difference in time between two locations on Earth was a measure of the east-west distance between these locations — in other words, their longitude. But, as no seaworthy clocks had yet been invented, seamen turned to the skies. Sailors had used stars such as Polaris to determine how far north or south they had sailed to find their latitude for decades. Now the race was on to find a celestial method to measure longitude.

One idea occurred to Galileo Galilei in 1609 when he discovered four moons orbiting the giant planet Jupiter in 1609. As Galileo watched these little moons whip around Jupiter, he realized they could serve as a grand celestial clock, ticking steadily for all observers. Almanacs could be created listing when moons would appear and disappear behind Jupiter for a reference location. Observing the difference in the local time of these events versus the times in the almanac would yield the difference in longitude. Unfortunately, using a handheld telescope on the deck of a rolling ship proved nearly impossible. Something bigger was needed: the Moon.

The lunar-distance method, suggested in the 16th century, proved to be more accurate. The idea is to use the Moon's motion as a clock: It moves quickly through the sky, roughly its own width every hour. All you needed was an instrument to measure the angle between the Moon and a reference star, an almanac with precise calculations of that angle for given times, and the mathematical ability to solve a spherical triangle! It sounds straightforward, but minds like Isaac Newton's were needed to explain the dynamics of the Sun-Earth-Moon system.

Newton's headache

To measure the angular separation of celestial objects, sailors had been using a device called the quadrant since the 15th century. But navigational equipment improved rapidly



throughout the 17th century, culminating in the 18th-century development of the sextant. This device delivered higher precision by incorporating a micrometer to make fine angular measurements. Detailed star charts were also being created. The real problem was understanding the Moon's motion well enough to produce accurate almanacs.

With his first law of planetary motion, Johannes Kepler showed that planets and their satellites move in elliptical orbits. This helped to explain many observational problems. Decades later, Newton developed his laws of motion and the theory of universal gravity. In the 1690s, Newton used his work to explain variations in the Moon's motions.

Newton understood that both the Sun and Earth pull on the Moon. The outcome of this tug-of-war varies depending on the changing positions of all three objects, making it extremely difficult to determine the Moon's exact position at any given moment. Now known as the three-body problem, it caused Newton no end of grief. Newton told Edmund Halley that the problem kept him up at night and gave him headaches. Newton was able to make sense of the two-body problem, but was unable to completely solve the three-body problem.

However, he did establish the groundwork for understanding the laws of motion and universal gravitation. By taking into account the gravitational influence of other planets and even the shape of Earth, astronomers have been able to refine the motion and position of the Moon with great precision.

Round and round

How would the Moon's motion look from a vantage point high above the solar system? Many popular astronomy books have diagrams from this perspective. If the diagram were animated, the Moon might appear to trace a spiral as it circled Earth and also moved around the Sun.

But these diagrams are rarely made to scale. In truth, the Moon does not form a spiral — Earth's orbital speed around the Sun is much faster than the Moon's motion around Earth. As Earth speeds along at about 18 miles (30 kilometers) per second, the Moon looks a bit like a faithful dog trying to keep up with its master, at its side and then alternately falling behind and pulling ahead.

Looking from above, we might intuitively think of this motion as resembling a sine wave crisscrossing Earth's path. But even this image isn't quite correct!

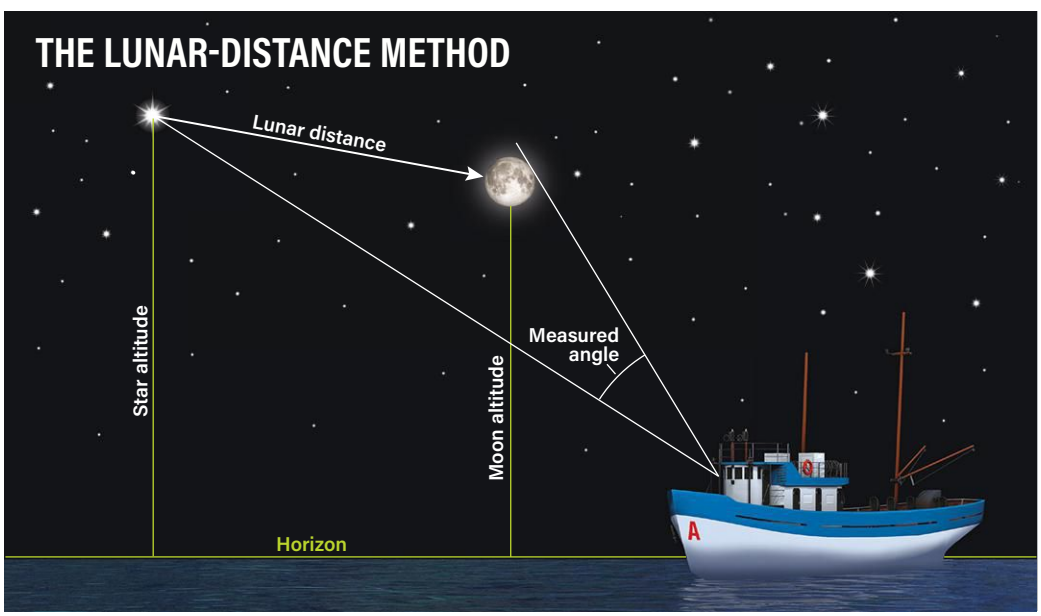
In truth, the Moon is pulled by the Sun's gravity with a force that is more than twice as strong as Earth's pull on the Moon. As a result, the speed of the Moon around Earth is so much slower than its motion around the Sun that its path never curves away from the Sun. The Moon's path does crisscross Earth's path twice a month, but this wobble is slight — not enough to resemble a wave.

This view of the Sun-Earth-Moon system provides a better idea of the push-pull effect created by gravity. It's easy to understand Newton's throbbing head.

From this perspective, the Moon appears to actually orbit the Sun, with its orbit almost imperceptibly disturbed by Earth's pull. Some (including science-fiction author Isaac Asimov) have even argued that the Moon should be considered a planet, coequal with Earth — two bodies traveling together around the Sun.

But when considering the Earth-Moon relationship, the reality is that the two bodies orbit a common center of gravity called the barycenter. As this point is located inside Earth — roughly 1,000 miles (1,700 km) below its surface — most consider the Moon to be Earth's satellite.

Astronomers have been challenged by the Moon's complex motions for centuries. This story only touches on a few of them. For most of us, however, the beauty of the ever-changing Moon is a sight that will always be amazing and intriguing.



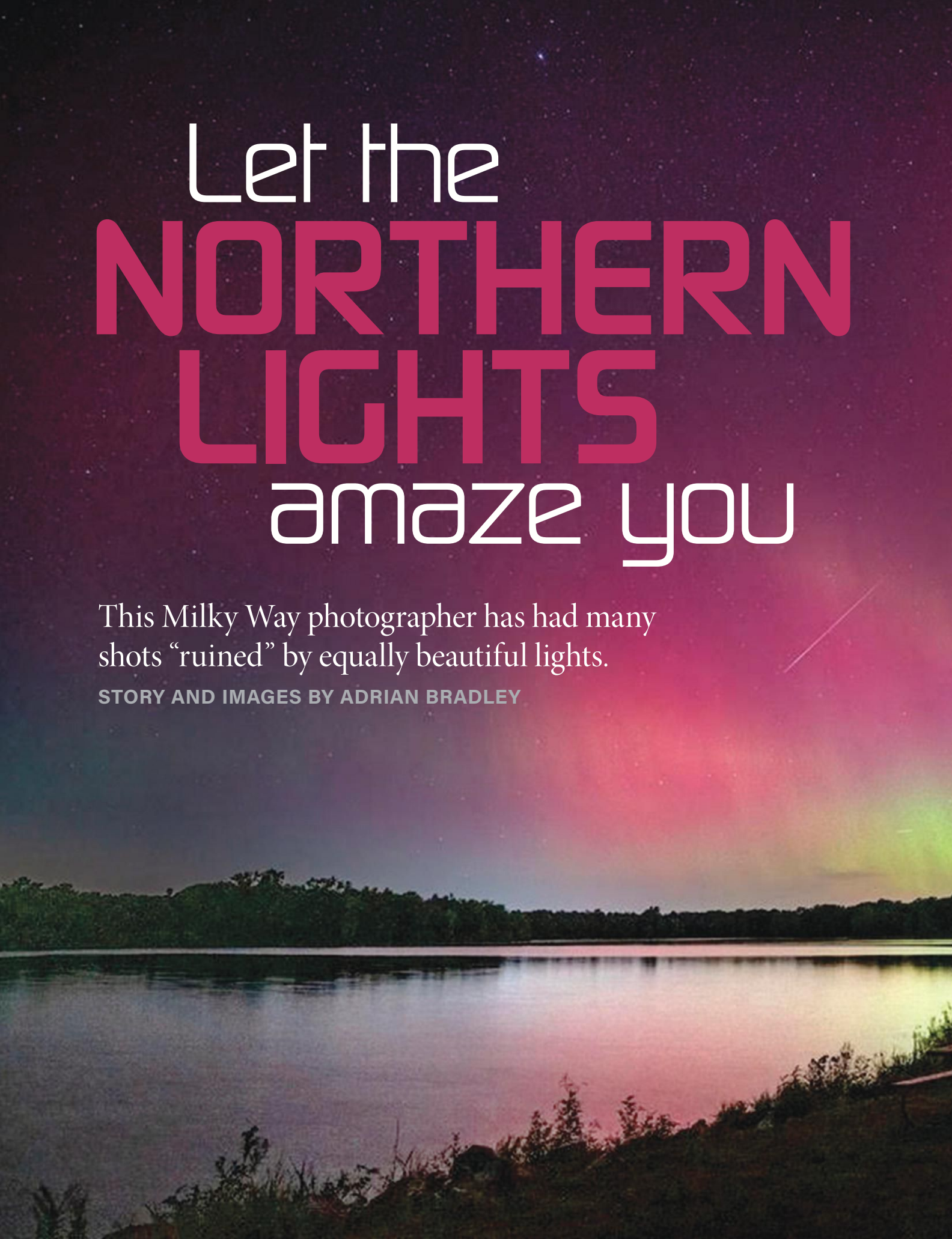
The lunar-distance method used an angle-measuring tool, like a sextant or octant, and almanacs of the Moon's and stars' positions to establish a reference time (such as Greenwich Mean Time). The objects' altitudes above the horizon indicated local time, and the difference in times yielded one's longitude. *ASTRONOMY:* ROEN KELLY

Raymond Shubinski *is a long-time contributor for* Astronomy *magazine who loves recovering the lost ephemera of astronomy.*

Let the NORTHERN LIGHTS amaze you

This Milky Way photographer has had many shots "ruined" by equally beautiful lights.

STORY AND IMAGES BY ADRIAN BRADLEY



THIS IS MY OPEN LETTER TO ALL AURORA CHASERS.

After returning home from a successful trip to the 2024 Okie-Tex Star Party in early October, I received alerts from SpaceWeather.com indicating increased activity on the Sun. Predictions called for a severe geomagnetic storm, with a chance of auroral activity as far south as Alabama.

I silenced those alerts and went to bed.

Some of you may wonder why I didn't immediately get excited, gas up the car, and bring my gear out to try and get some aurora pictures. Well, let me tell you my story.

My history with aurorae

Before getting into photography, I had a chance to see an auroral outburst in 2003 in Wisconsin. It was during another active solar cycle. I wasn't much into astronomy then, but I recognized it as an aurora, stopped the car I was driving, watched for a few minutes, and locked the unforgettable sight in my mind.

Within a year I would see auroral curtains near my home in Michigan. Back then, there were no alerts for possible auroral activity. If you happened to be out when the aurora was going, you saw it.

During the peak of the Perseid meteor shower, the shooting stars were upstaged by an auroral burst. The author captured this image from Lake Hudson State Park in Clayton, Michigan.

Nowadays, it is possible to know when a coronal mass ejection (CME) has occurred, and if its trajectory intersects Earth. When we get these alerts, we realize that in a day or two there may be an aurora. There are many other factors involved, but they're out of our control. So, there's still quite a bit of luck involved in getting yourself to a place to see aurorae. Then, once you set up, you may see anything from a faint glow on the horizon to a visibly colorful aurora dancing in the night sky. Or you may see a lot of clouds or nothing.

Aurorae and social media

With all of the advanced alerts dedicated to aurorae, we have chasers racking up lots of miles. With every outburst, a new set of people decide they want to see the aurora for themselves, and they join groups of chasers. These groups don't promise sightings, but in forums and on social media, we have a routine that goes like this:

Chaser A: There is a big chance aurora will happen!

Chaser B: I'll be at (some place), join me.

Naysayer Norman: It probably won't be any good.

Negative Nancy: It's going to be cloudy.

Chaser A: Forecasts have dwindled.

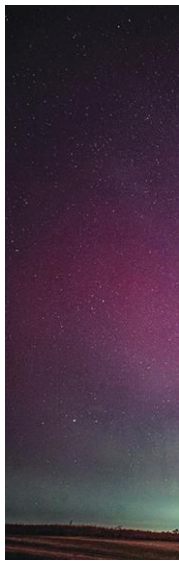
Know-It-All Nolan: It's not worth it, another false alarm.

LEFT TO RIGHT: The author thought the light behind him was a flashlight. Instead, he set up a tripod and captured this image of an aurora with a Sony A7R4 camera and a 24mm f/1.4 GMaster lens, taken from Lambton Shores, Ontario.

When he set out to photograph the Milky Way outside of Clinton, Michigan, the author had no idea that this colorful display would hide it. The three stars of the Summer Triangle are barely visible.

Here the author sits lakeside near Lambton Shores, Ontario. He used a short exposure to capture the scene as it appeared to his eyes.

BELOW: When the author took this image in 2021 from Pointe aux Barques Lighthouse Park in Port Hope, Michigan, he thought it was a great display from that latitude. Much better shots lay ahead.



Super Astrophotographer Andy: I got a great image back when I went to Iceland, check this out.

The next day:

Chaser B: Well, I was by myself, but it was an amazing display. Here are some pictures from my phone.

Chaser A: Very good. I saw later that an outburst did occur for a short time.

Negative Nancy: That picture is fuzzy, it must not have been very bright.

Naysayer Norman: The aurora must have been faint, it only looks halfway decent because of your camera.

Super Astrophotographer Andy: It's all right, but doesn't compare to this overhead photo that I got from Alaska.

Know-It-All Nolan to Super Astrophotographer Andy: Is that an AI-generated image? That can't be real! Aurora isn't that bright in real life.

In all pursuits we find characters like this in social media forums. Unfortunately, there's no stopping the self-serving banter that discourages others from enjoying chasing of the northern lights.

My view is if there is any chance of aurorae happening, embrace it, let the people chase, and don't write anything negative in a forum if you can't write something positive. The love of aurorae and all things astronomy shouldn't be about ourselves; it should be about whatever is going on in the night sky that captivates many. Those who love chasing aurorae face a lot of dark nights with nothing but skyglow. But they get lots of healthy endorphins when lights seem to just explode all over the sky.

May 10, 2024

Make no mistake, I'm not an aurora chaser. I'm a Milky Way photographer. I go to star parties to see it in all its glory, from horizon to horizon. I also travel to other dark sites to take pictures of all aspects of the Milky Way, and at different times of night, including twilight. Only in really dark and transparent regions on Earth can you see the Milky Way beginning to appear in twilight. That's when you know it's bright.

It was precisely nautical twilight on May 10, 2024, in Lambton Shores, Ontario, when an amazing display began. At the time, I thought the only way I'd see aurora at that latitude was on the horizon.

Lots of you probably have seen aurorae as a faint glow of green or red on the horizon. To you, the northern lights may not be much of a big deal, and only look good when photographed. Well, I may not be an aurora chaser, but that night taught me one thing — we skeptics are wrong about how amazing the aurora can be.

The May 10 geomagnetic storm drew comparisons to the Carrington Event of September 1859. The others were good for smaller periods of time but captivating to those who were able to see them. Here's how the events that night unfolded for me.

I was setting up one of my cameras when I detected a bright light to my left. "Who's got a flashlight on?" I shouted out to no one in particular. "I'm trying to set up for aurorae."

The light persisted. I turned in its direction but saw no one there but a gentleman who wasn't holding a flashlight. I then realized the source of the light was coming from above him. When I looked up, I saw something I'd never seen in an aurora before, nor had I ever seen it so brightly above me. The curtain was angled towards the zenith, and it appeared to be right on top of me!

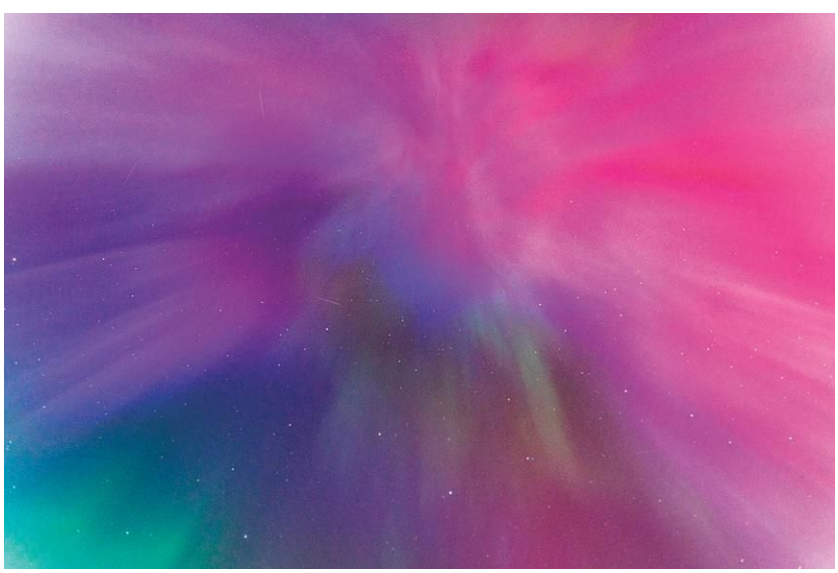
I also saw the so-called "Corona Borealis," which is when you see the lights dance at the zenith and "pour" around you on all sides. This is another hint that the aurora is directly above your location, and the colors are easily naked-eye visible.

Then I saw the raging aurora on the horizon in all directions. The pinks, reds, and greens were

ABOVE: This composite image shows the colorful northern lights and light from the waxing crescent Moon reflected off of a lake near Lambton Shores, Ontario. It reproduces what the author saw with his eyes.

RIGHT: When the northern lights appear as a giant, colorful flower overhead, some photographers refer to the display as the Corona Borealis.

MIDDLE AND FAR RIGHT: The author's camera recorded these images before it got dark enough to see the aurora with his eyes.



easily visible. People had come to this park to camp and were stunned as they filtered onto the beach to watch. We had a major light show on our hands!

I aimed my camera in every direction. I finally set up a composite so that the waxing crescent Moon, slowly setting, would show as it looked to the human eye. Some of the colors, such as blue and yellow, would show up well in an image I took looking out over Lake Huron. This would be one of my favorite shots of this bright, colorful phenomena.

And I do mean bright. I could tell as night fell that the lights from the towns were not as bright as the aurora in the sky. This was new for me.

This geomagnetic storm was strong enough for people to walk outside and take pictures of the aurora with smartphones. Then they took over the internet for a day and a half. I posted a few images, but, as expected, they got lost in the crowd. We were literally flooded with aurora pics from that event.

Because I saw that event firsthand, along with other outbursts and getting some decent images, I've reached a level where I'm content. But I respect other peoples' desire to see this phenomenon repeatedly. I feel sad for those who want to see it, but have the cares of life drown out their opportunities to do so. And I also feel for those who spend a lot of money to take a trip to a location such as Iceland or Alaska, only to be clouded out or not see much due to the Sun refusing to spew CMEs our way while people take the trips. I also smile when I read of aurora chasers seeing a major outburst and regarding it as the best ever. How soon we forget our other best-ever moment, even if it was just a few months ago. I guess we tie our emotions to seeing such beauty in nature.

Is the Big One ahead?

Are we due for a really big outburst that rivals, or even matches the Carrington Event? If we get one, there will be both amazement and chaos. The aurora will dance overhead and smartphones will be on hand to record it and flood the internet. That is, if phones and our very infrastructure haven't been blown out!

If they are, the first thing people may notice is how slow their social media platforms are to upload the fantastic pictures they've taken. Then comes the realization that power is out at their location. The amazement of seeing the aurorae gradually gets replaced by the horror that things don't work. We could be in the throes of a Carrington-like event.

During the original Carrington Event, the activity in Earth's magnetic field was so strong it induced electrical currents in telegraph wires, causing sparks and fires. After telegraph operators removed their power supplies, they realized they could still send messages using the current induced by the geomagnetic storm alone. It must have been as shocking to them as it would be to us if, during an auroral storm, our smartphones suddenly began wirelessly charging.

One thing's for sure: If I were a power company, it would be a good time to make sure there's a lot of insulation and grounding for our devices. With each auroral outburst I'd be taking readings and making sure I'm fending off external sources of power so as not to be overloaded. I'd also be preparing to act in the event we do get hit with a major CME that blows satellites out of low Earth orbit and threatens to create chaos all over the planet.

And if those power companies succeed in shielding us from the worst, then that will turn into the best aurora display of our generation. It'll be remembered fondly by aurora chasers with tears in their eyes and camera memory cards that are too full to take another image.

Until that happens, I'll leave the chasing to everyone else and go do some more creative Milky Way photography.

Adrian Bradley *resides in Belleville, Michigan, and loves imaging the night sky, even in cold weather.*

Delights of the Southern Sky

Most of the good stuff lies south of the equator.

LEFT: The author captured Omega Centauri (NGC 5139) with one hour of exposure when it was 10° above the horizon east of Tucson through an Astro-Tech 72ED refractor. MOLLY WAKELING

RIGHT: The Large Magellanic Cloud was the author's target in July 2019 when she was near San Pedro de Atacama, Chile. She captured two hours of exposure using an astromodified Sony a7s and a Rokinon 135mm f/2 lens. MOLLY WAKELING

BY MOLLY WAKELING
Molly is an avid astrophotographer active in STEM outreach. She has a Ph.D. in nuclear engineering.

The Northern Hemisphere skies may offer many treats for the eyes, but we who live under them often pine for the delights unique to the southern sky. Those lucky southern astronomers get to see the Milky Way's core overhead rather than along the horizon, and enjoy many star clusters and nebulae that are hidden for us in the north. If you have the chance to travel to the Southern Hemisphere, be sure to check out some must-see highlights.

I had the opportunity in 2019 to view the July 2 total solar eclipse in Chile, where I also spent a week in the Atacama Desert. Using one of the telescopes in French expat Alain Maury's sunflower field of Dobsonian-mounted reflectors at his Atacama Lodge outside San Pedro de Atacama, I observed several objects I had never seen before, along with familiar targets such as the Swan Nebula (M17) and the Lagoon Nebula (M8) lying almost directly overhead. The high altitude and dark sky made for some incredible nights of observing.

Some of my favorite objects to espy in big Dobs are globular clusters, and with a full view of the Milky Way's core, the southern sky is replete with them. First and foremost is Omega Centauri (NGC 5139), a spectacular sight with some 10 million stars. It's so big and bright that it was visible naked-eye even from our hotel in the large coastal town of La Serena, where we stayed before the eclipse. In a 28-inch reflector, it's breathtaking.

First and foremost is Omega Centauri (NGC 5139), a spectacular sight with some 10 million stars.

Another stunning glob is 47 Tucanae, the second-largest in the sky after Omega Centauri. I wrote in my logbook that it "seemed to spiral around in my eye."

Of course, we can't forget about the most impressive object in the southern sky — the Tarantula Nebula (NGC 2070), located in the Large Magellanic Cloud. One of the fascinating things about it is that it looks different at every magnification. Under low power, I wrote that it had "three chunks" and looked "dim and chunky." With higher magnification, I was awestruck by its intricate structure and color, which is incredible considering it's 160,000 light-years away. I wrote that the nebula "showed a green-blue color, forked with dark nebulous clouds spreading out from the middle." If the Tarantula were as close to us as the Orion Nebula, it would be as large as 60 Full Moons side by side and would cast shadows!

It's also worth stopping by the planets and northern-sky objects while in the Southern Hemisphere. I had some of the sharpest views I've ever seen of familiar targets as they appeared overhead, where there is the least atmosphere between you and space. I could see more structure in M17 than before, and Jupiter and Saturn were full of detail. I swung by the Silver Coin Galaxy (NGC 253) in Sculptor, which I noted looked "positively 3D … standing out against the background darkness."

The good news for northern observers is that several objects commonly thought to be for southern observers only are actually visible from southern parts of the U.S. From my dark-sky property outside Tucson (latitude 32° north), I've observed Omega Centauri through binoculars and captured it with my astrophotography rig; it rises as high as 10° from there.

I've also observed it and the starburst galaxy Centaurus A (NGC 5128) while at the Texas Star Party. The Carina Nebula (NGC 3372) and the glittering Jewel Box Cluster (NGC 4755) are reportedly visible from the Winter Star Party in the Florida Keys, as is the nearest star system, Alpha Centauri, in the summertime, if only a few degrees off the horizon.

Observing the southern skies from Chile is an experience I won't forget. If you have a chance to travel south, take it! For those of us stuck in the north, we'll have to make do with catching a few southern delights when they briefly sneak over the horizon.

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CANYON AND COSMOS:
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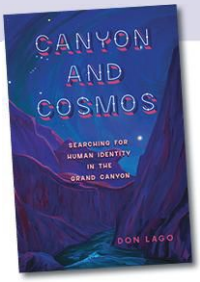
By Don Lago



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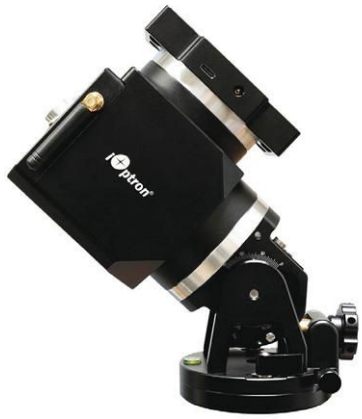

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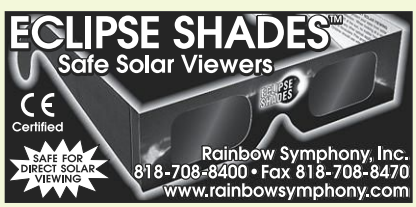

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Galactic supernovae

Q | ASTRONOMERS SAY OUR GALAXY HASN'T SEEN A SUPERNOVA IN 400 YEARS. WHY DON'T THEY COUNT THE 1987 SUPERNOVA?

Judy Pearce
Belton, Texas

A | The 1987 supernova (SN 1987A) occurred in the Large Magellanic Cloud (LMC), not the Milky Way. The LMC is a smaller satellite of the Milky Way, but astronomers still consider it to be outside our galaxy. The 400-year figure refers to visual observations of supernovae in the Milky Way Galaxy itself.

Astronomers know other supernovae have occurred in the Milky Way since 1604, when Johannes Kepler observed one. But once scientists account for all known remnants and their ages, the Milky Way's supernova rate still seems lower than that of other spiral galaxies. Astronomers suspect they've either misidentified or overlooked some remnants.

Of course, just because we don't see supernovae doesn't mean they aren't occurring. Dust in our galaxy's disk prevents a lot of light from reaching us. Infrared and radio wavelengths can penetrate this dust and reveal new remnants. Then, astronomers can watch how fast the remnants expand and figure out how old they are.

Supernova remnant Cassiopeia A, the brightest celestial radio source beyond the solar system, is only about 300 years old. The only recorded sighting was by John Flamsteed on Aug. 16, 1680, when he cataloged a star in the remnant's position.

The Milky Way's youngest known supernova remnant is a radio source called G1.9+0.3. The remnant, which lies 27,700 light-years away, is only about 140 years old. This means the supernova's light swept over Earth about 140 years ago, but it took 26,000 years for light from the blast to reach us.

Radio astronomers using the Very Large Array (VLA) in New Mexico found that G1.9+0.3 grew by 16 percent between 1985 and 2008. That corresponds to an expansion velocity of 30 million mph (48 million km/h), or about 5 percent of light-speed. Because it's so young, G1.9+0.3 is still getting hotter and brightening at radio frequencies.

WHAT A DIFFERENCE TIME AND DISTANCE MAKE!

Supernova remnants usually glow, thanks to interstellar gas heated by the explosion's expanding shock wave. But astronomers say most of the energy G1.9+0.3 radiates arises from the debris of the exploded star.

Francis Reddy
Senior Science Writer, Astrophysics Science Division at NASA's Goddard Space Flight Center, Greenbelt, Maryland

Q | ARE EITHER OF THE VOYAGER SPACECRAFT CAPABLE OF TAKING A PICTURE OF OUR SOLAR SYSTEM FROM THEIR CURRENT INTERSTELLAR LOCATIONS?

Jake Cunningham
Eugene, Oregon

A | No, but let's talk about how the spacecraft that once dazzled scientists and the public alike with images of our solar system came to this state.

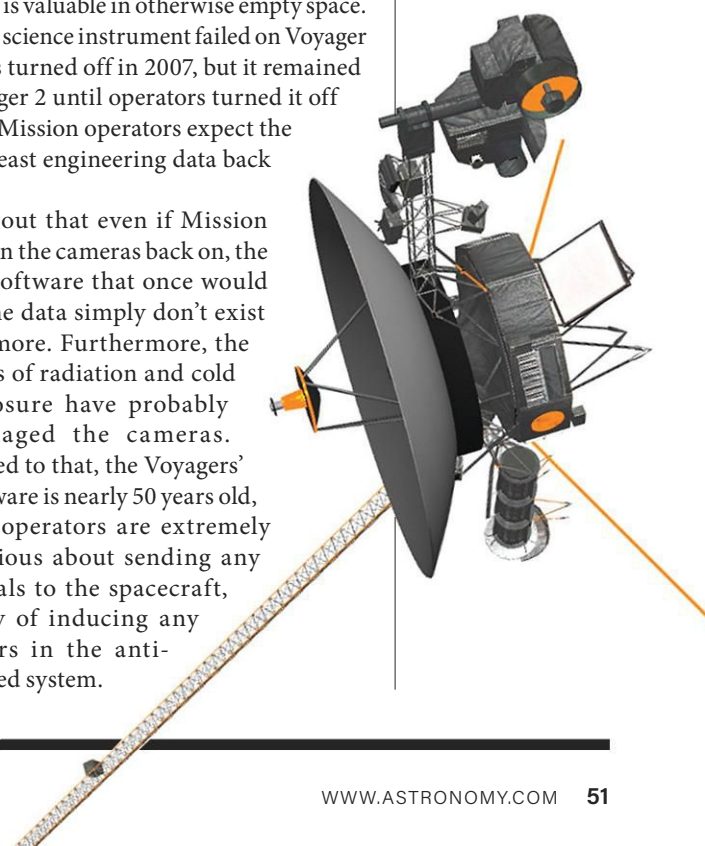
To preserve power and memory, mission operators turned off all the Voyager cameras between late 1989 and early 1990, when they had wrapped up their tour of the solar system. Voyager 1 took the last picture, affectionately known as the solar system family portrait, on Feb. 14, 1990. While the spacecraft are still functioning today, most of their other instruments have also been turned off for the same reasons. Plus, in the depths of interstellar space, there simply isn't much to observe.

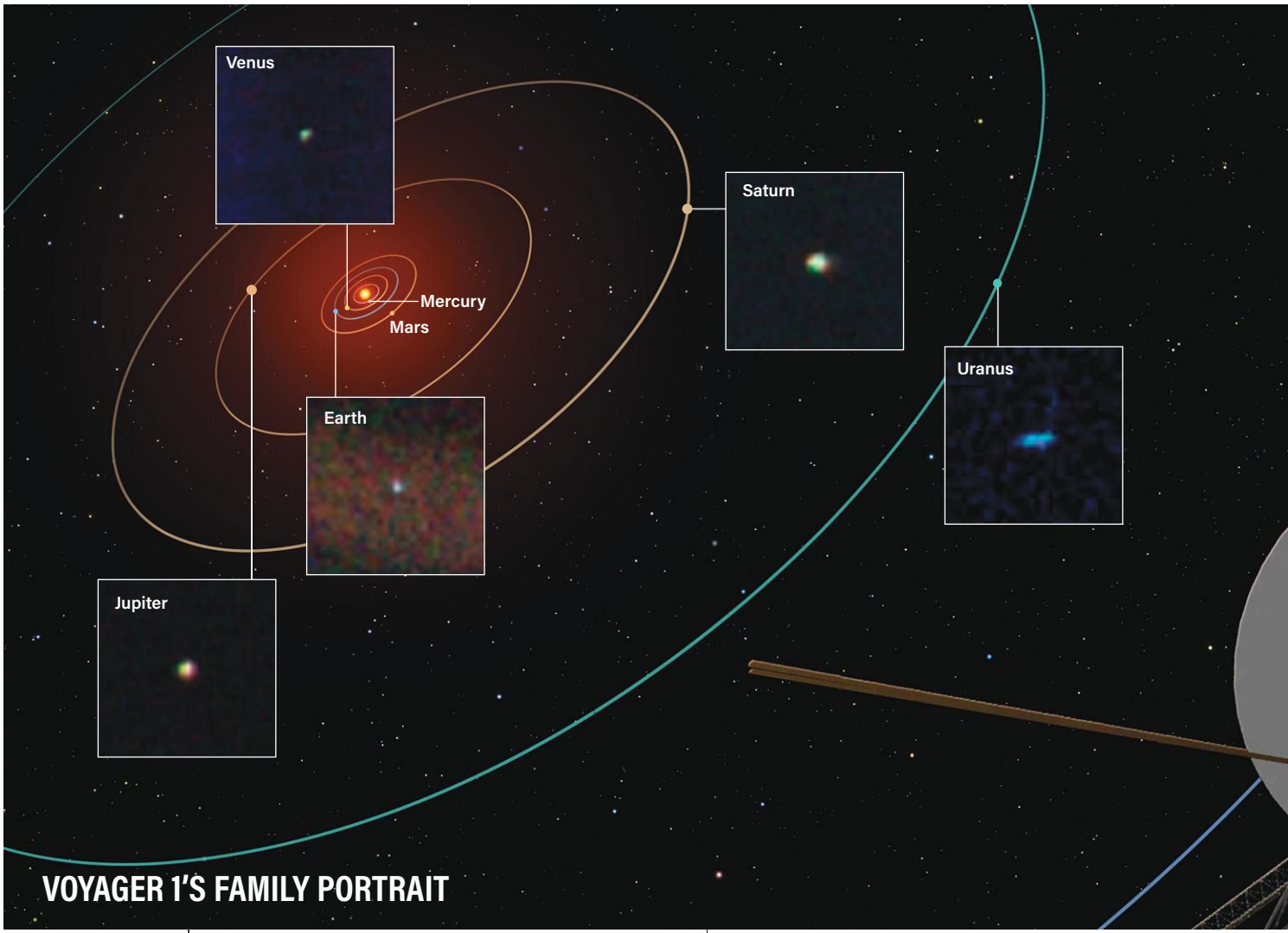
The spacecraft still have three functioning instruments each, built to measure cosmic rays, magnetic fields, charged particles, and plasma waves — the science that is valuable in otherwise empty space. A separate plasma science instrument failed on Voyager 1 in 1980 and was turned off in 2007, but it remained working on Voyager 2 until operators turned it off in October 2024. Mission operators expect the crafts to send at least engineering data back until 2036.

NASA points out that even if Mission Control could turn the cameras back on, the computers and software that once would have analyzed the data simply don't exist anymore. Furthermore, the years of radiation and cold exposure have probably damaged the cameras. Added to that, the Voyagers' software is nearly 50 years old, and operators are extremely cautious about sending any signals to the spacecraft, wary of inducing any errors in the antiquated system.

OPPOSITE PAGE: SN 1987A (at center) is one of the most well-documented supernovae in history. However, it did not occur in the Milky Way, but in the Large Magellanic Cloud, some 163,000 light-years away. NASA, ESA, ROBERT P. KIRSHNER (CFA, MOORE FOUNDATION), MAX MUTCHLER (STSCI), ROBERTO AVILA (STSCI)

BELOW: This model shows one of NASA's twin Voyager spacecraft, both of which launched in 1977. ALEKSANDR/ADOBE STOCK





This simulated view shows Voyager 1's view back through the solar system, creating a "family portrait" of the planets: Venus, Earth, Jupiter, Saturn, Uranus, and Neptune. These were the last images taken by the craft, on Feb. 14, 1990, before its camera was shut off to preserve power. NASA/CALTECH, *ASTRONOMY*: ROEN KELLY

And if the cameras were turned on, the dark of space means they wouldn't image anything in particular. The cameras were built to take pictures of big planets and their moons that gleamed in the Sun's light as Voyager buzzed by. The spacecraft don't have telescopes, so anything they see would be merely a dim point of light.

To put it in perspective, Saturn orbits at a distance of 9.5 astronomical units (AU, where 1 AU is the average distance between Earth and the Sun of 93 million miles [150 million kilometers]). Voyager 2 (the closer of the twin spacecraft), is currently 140 AU from the Sun, meaning you are 16 times closer to Saturn than Voyager is.

So even if they could take a picture, your phone could take a much better one. What a difference time and distance make!

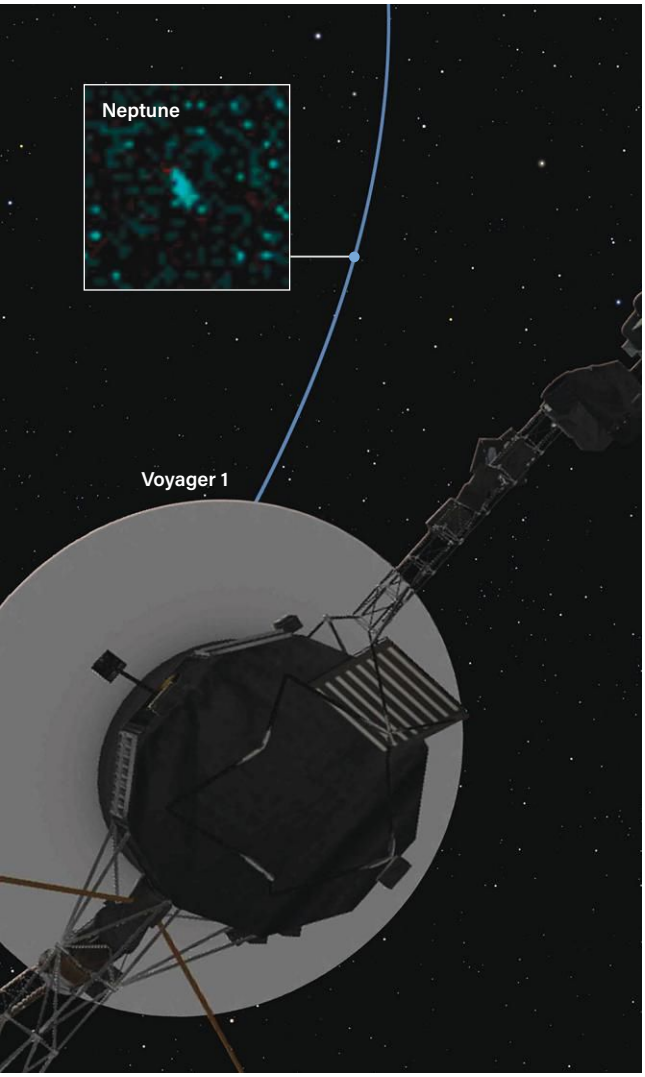
Korey Haynes
Contributing Editor

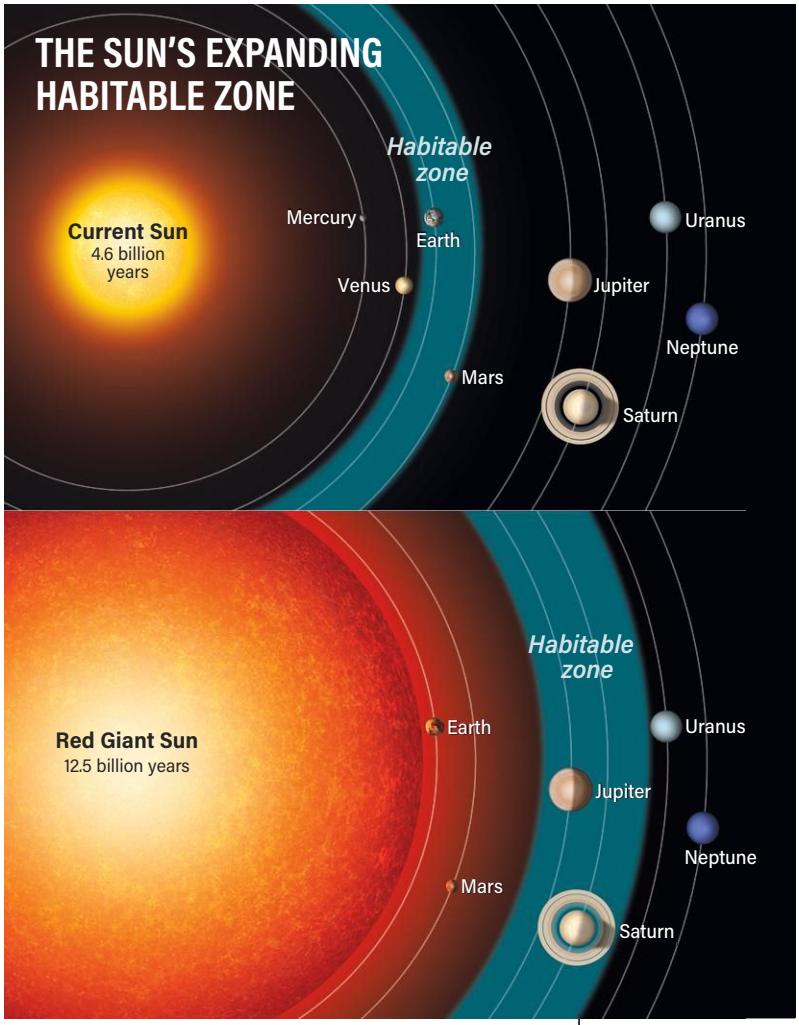
Q WHEN THE SUN BECOMES A RED GIANT, WILL THE OUTER PLANETS AND MOONS BECOME MORE TEMPERATE AND CONDUCIVE TO EARTH-LIKE LIFE?

Terrence A. Murray
Cincinnati, Ohio

A When the Sun runs out of hydrogen fuel and expands into a red giant, it will eventually encompass the innermost planets of the solar system, out to about Earth's orbit. Being closer to our enlarged central star will mean drastically hotter temperatures in the planets that remain in the outer solar system, as well as their moons.

Alan Stern, a researcher at the Southwest Research Institute (SwRI) and expert on the Kuiper Belt, writes in a 2004 *Astrobiology* article that during our Sun's red giant phase, the habitable zone where liquid water can exist will shift out to some 10 to 50 AU. So, more





The habitable zone (shown here in teal) is the region around a star where temperatures are right for a planet's surface to sustain liquid water. As our Sun expands and heats up in its red giant phase, its current habitable zone, which now encompasses Earth, will move outward.
ASTRONOMY: ROEN KELLY

temperate? Certainly. But let's explore the trickier part of your question: Will those regions become more conducive to life?

The four outer planets don't have any solid surface to speak of, and do have enormously deep atmospheres made largely of the light elements hydrogen and helium. Traditionally, astronomers thought planets like these would be blown apart if they orbited close to their stars, but we now know of quite a few examples of hot Jupiters — gas giants tightly orbiting their stars, albeit with extended atmospheres, much like a puffed-up marshmallow. So it's possible that these planets might remain intact as the Sun expands, but they won't become any better prospects for life.

The answer is more optimistic for some of their moons, where astronomers have long searched for clues to habitability. Moons including Enceladus, Europa, Titan, and Triton all probably have oceans of water under their surface. And that's not to speak of all the dwarf planets in the Kuiper Belt, including Pluto, many of which have at least some water currently locked up in the form of ice, either on or below the surface. Rich organic materials, another requirement for life, also appear over and over again in the outer solar system.

Astronomers speculate even now about the possibility of life in the subsurface oceans we know about. If more worlds became warm and wet with an expanded habitable zone, the options would only increase. Stern also points out this "delayed gratification habitable zone," as he calls it, would suffer fewer collisions and less harmful solar radiation than the traditional (current) habitable zone, which could increase chances for life.

On the other hand, we still don't know how life came about on Earth to begin with. And because the habitable zone shifts even during the red giant phase as the Sun continues to evolve, no planet in our solar system will spend more than half a billion years in the new habitable zone — and it took just about that long for life to develop on Earth. Can our solar system do it again? We'll find out … in about 5 billion years.

Korey Haynes
Contributing Editor

SEND US YOUR QUESTIONS

Send your astronomy questions via email to **askastro @astronomy.com**. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

READER GALLERY

1. MORE THAN A SPIRAL
NGC 1512 is a barred spiral galaxy with a unique double ring roughly 33 million light-years distant in the southern constellation Horologium. Ultraviolet space telescope views reveal the full extent of the spiral arms, and how distorted they are by the galaxy's gravitational tango with NGC 1510, at right. The imagers took 17¾ hours of exposure for this LRGB image with a 17-inch scope. ▪ ***Bob Fera/Steve Mandel***

2. SOUTHERN SHOWCASE
The Carina Nebula (NGC 3372) is the sky's most impressive emission nebula for visual observers. But also pictured is NGC 3324 (at left), an open star cluster that appears to lie within a blue lagoon in this wide-field, Hubble-palette image taken with a 6.3-inch scope and more than 36 hours of exposure. NGC 3324 is perhaps best known as the home of the Cosmic Cliffs — a region imaged by both Hubble and the James Webb Space Telescope. ▪ ***Josh Jones/ Kaptas Attila***

3. SOLAR SCOPE
The McMath-Pierce Solar Telescope stands beneath a dark, moonless sky at Kitt Peak National Observatory in Arizona. The photographer combined 90 one-minute exposures with a Canon DSLR at f/2.8 and ISO 2500. ▪ ***Chris Cook***

4. THE LUNAR SOUTH
Craters dot the Moon's rugged south pole region in this shot taken March 7 with a 16-inch Dobsonian. The central-peak crater just above and left of center is Moretus, and Clavius is the large crater at lower right (with multiple smaller craters inside). At far upper left, in deep shadow, lies Mons Mouton — the destination of the ill-fated IM-2 mission. ▪ ***Jamie Cooper***

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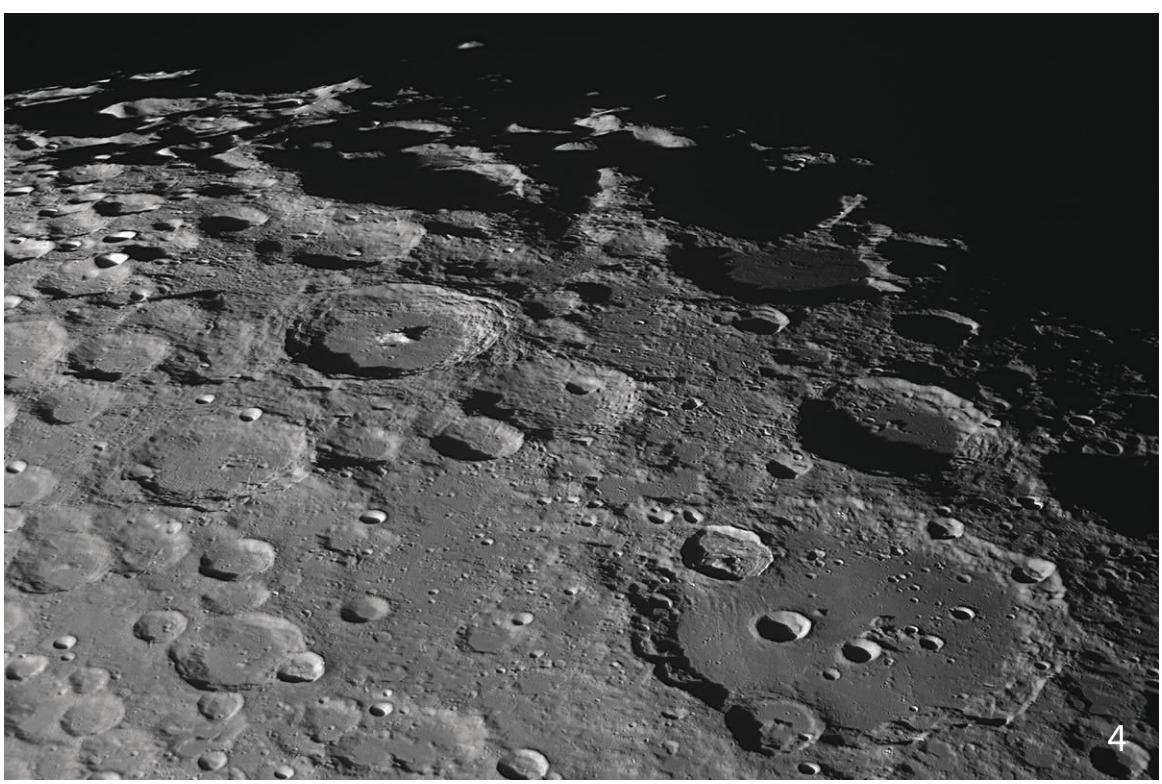
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5. LIGHTING UP THE NEIGHBORHOOD
The dark nebula Barnard 37 in Monoceros is surrounded by an entourage of reflection nebulae in this scene — most prominently IC 447 (at lower left), which is visually connected by a trail of dark dust (LDN 1607) to IC 446. NGC 2245/7 are another pair of reflection nebulae at top center. The imager used a one-shot color camera to take 20 hours of exposure with a 6-inch scope.
• ***Chiradeep Chhaya***

6. BIG GREEN APPLE
The elusive green flash appears when warm air trapped beneath cold air causes longer wavelengths of light to be bent away from the viewer as the Sun nears the horizon. In this image, a green flash appears behind the Manhattan skyline, anchored by One World Trade Center.
• ***Chirag Upreti***

5

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HUBBLE SPOTS A COSMIC BULLSEYE

Sometimes even scientists get lucky. Yale University astronomer Imad Pasha was scanning some ground-based images when he stumbled across a galaxy boasting several rings. Because the object's name, LEDA 1313424, doesn't roll off the tongue, his team nicknamed it the Bullseye. This Hubble image reveals why it's an apt moniker: The galaxy boasts nine rings, six more than any other known. The rings formed like ripples in a pond after a blue dwarf galaxy ripped through LEDA 1313424's heart some 50 million years ago. (The interloper appears just left of center.) The collision triggered the birth of hot blue stars in the outer two rings, while the redder inner rings pile up near the center. The galaxy spans 250,000 light-years, 2.5 times the Milky Way's size, and lies 570 million light-years away in the constellation Pisces. NASA, ESA, IMAD PASHA (YALE), PIETER VAN DOKKUM (YALE)

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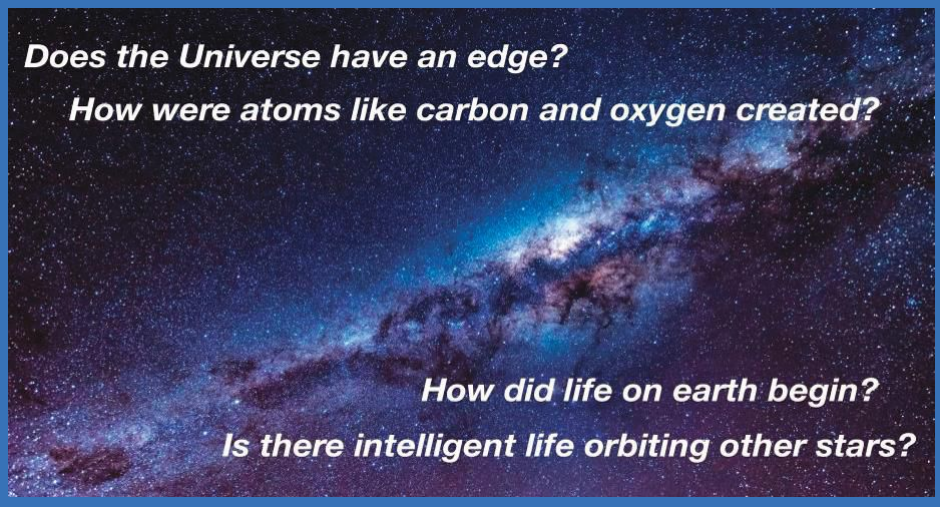
June 10, 2025 thru September 30, 2025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Is there intelligent life orbiting other stars?

Dr. George Roush will explore

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August 2025
Venus meets Jupiter at dawn

Although **Mars** reached opposition in January, it remains a fixture on August evenings. In fact, it's the only planet visible as twilight fades to darkness. The planet moves eastward against the background stars of Virgo, approaching that constellation's luminary, 1st-magnitude Spica. The magnitude 1.6 Red Planet makes a nice color contrast with the blue-white star.

Unfortunately, Mars lies on the opposite side of the Sun from Earth and thus appears small through a telescope. Its 4"-diameter disk won't show any detail.

Later in the evening, **Saturn** pokes above the eastern horizon. You can find it in southern Pisces, near that constellation's borders with Aquarius and Cetus. Saturn shines at magnitude 0.7, significantly brighter than any nearby star.

This gas giant world will reach opposition in September, but the view through a telescope this month is nearly as good. In mid-August, the planet's disk measures 19" across while the rings span 43" and tilt 3° to our line of sight.

No other naked-eye planet appears until the wee hours. Soon after Orion the Hunter's impressive figure clears the eastern horizon, the solar system's two brightest planets come into view.

Venus rises first in early August, a bit more than two hours before the Sun. It starts the month in far western Gemini, quickly traverses the Twins, and then enters Cancer in August's final week. On the 31st, Venus lies 2° southwest of the Beehive star cluster (M44).

The dazzling inner planet fades imperceptibly this month, from magnitude –4.0 to –3.9. Yet this brilliance doesn't portend a great telescopic appearance. Venus' diameter shrinks from 14" to 12" during August while its phase waxes from 75 percent to 84 percent lit.

On Aug. 1, **Jupiter** rises nearly an hour after Venus. The outer planet climbs higher with each passing day, however, and soon catches up to its sibling. The two meet on the 12th, with Venus sliding 0.9° south of Jupiter. For a couple of mornings, they will look like a pair of bright headlights in the twilight. Venus appears seven times brighter than magnitude –1.9 Jupiter.

Because the giant planet lies low in the morning sky, where the seeing tends to be poor, don't expect sharp views through your telescope. Still, you should see its 33"-diameter disk and its four largest moons.

Mercury emerges briefly before dawn in mid-August. The innermost planet passes between the Sun and Earth at inferior conjunction on the 1st and then climbs rapidly into view. Mercury reaches greatest elongation Aug. 19, when it lies 19° west of the Sun and stands 6° high in the east-northeast a half hour before sunrise. To find the planet, draw a line from Jupiter to Venus and extend it a bit more than twice that distance. Mercury shines at magnitude 0.0.

A waxing gibbous Moon occults the 1st-magnitude star Antares twice this month. The Aug. 4 event favors observers at the southern tip of South America. From Punta Arenas, Chile, the star disappears at 2h31m UT and reappears at 3h33m UT. Viewers in parts of New Zealand's South Island can witness the Aug. 31 occultation. From Christchurch, Antares disappears at 11h49m UT and reappears at 12h05m UT.

The starry sky

August certainly offers some of the finest evening views of the starry sky. Nothing quite compares with being under the spectacular Milky Way on a moonless night away from the lights of any towns or cities. This year, the Moon abandons the evening sky from around Aug. 12 to 24.

People sometimes ask me where the best place is to see the Milky Way. The easiest answer is any place without light pollution. But if you want a more technical answer, I would say the best *latitude* from which to view the Milky Way is around 29° south. That's where the center of the Milky Way passes directly overhead when the sidereal time is about 17h45m (early evening in mid-August). This latitude corresponds to southern Australia, southern Brazil and northern Argentina and Chile in South America, and South Africa.

That said, the brightest part of the Milky Way lies a few degrees east of the galactic center, in the so-called Large Sagittarius Star Cloud. It's easy to mistake this huge starry assemblage for our galaxy's entire central bulge. It is not, however — it represents only about one third of the bulge. The rest remains hidden behind thick clouds of galactic dust. As you gaze at the Milky Way, remember that its equator actually runs through the dark region adjacent to the Large Sagittarius Star Cloud.

Within this cloud lies the globular star cluster NGC 6522. English astronomer William Herschel discovered the cluster in 1784, three years after he first spotted the planet Uranus. The 8th-magnitude globular resides just 37' northwest of the magnitude 3.6 star Gamma^2 (γ^2) Sagittarii, making it easy to spot through a telescope or binoculars with an aperture of at least 50mm.

The region centered on NGC 6522 exhibits far less absorption of light than nearby areas. German astronomer Walter Baade studied this area with the 100-inch Hooker Telescope on California's Mount Wilson during the 1940s, which allowed him to estimate the distance to the center of our galaxy. Astronomers now refer to this relatively transparent part of the sky as Baade's Window.

STAR DOME

HOW TO USE THIS MAP

This map portrays the sky as seen near 30° south latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

9 P.M. August 1
8 P.M. August 15
7 P.M. August 31

Planets are shown at midmonth

MAP SYMBOLS

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

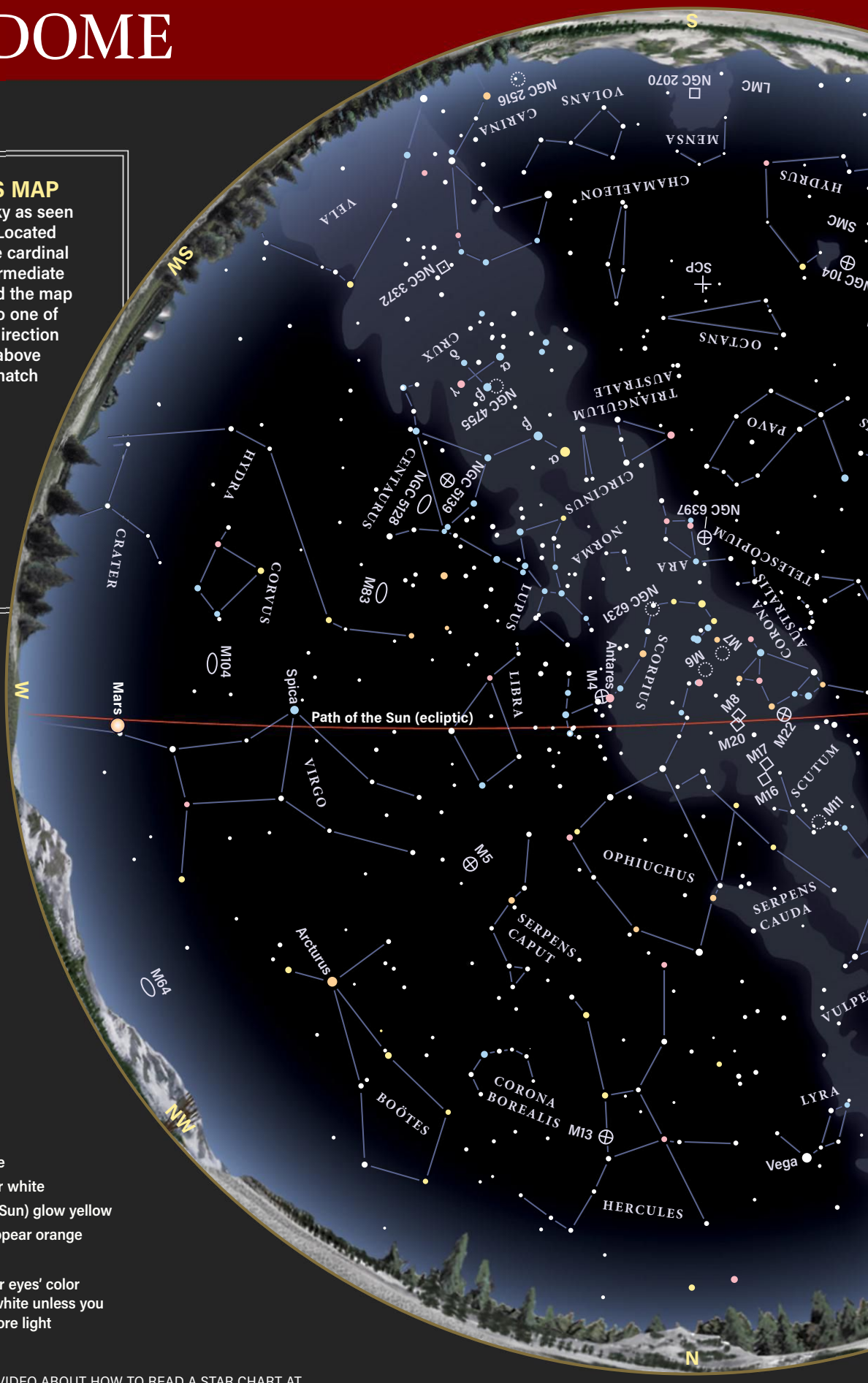
STAR MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light



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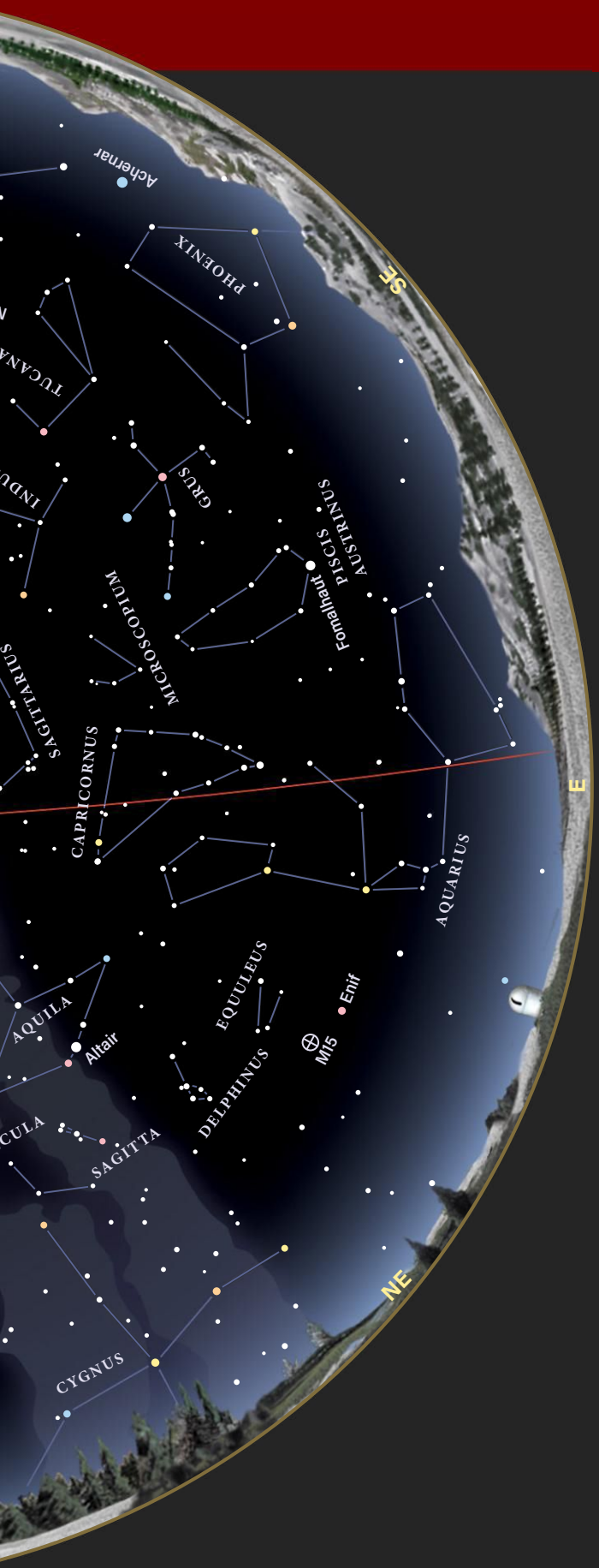


AUGUST 2025

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

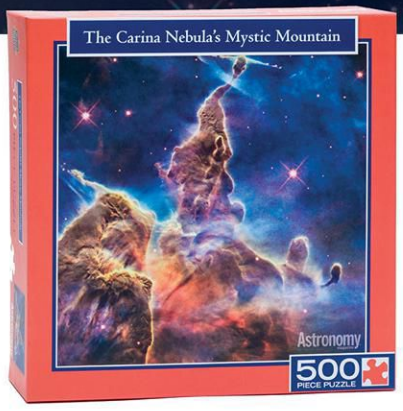
ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

1 Mercury is in inferior conjunction, 0h UT
First Quarter Moon occurs at 12h41m UT
The Moon is at apogee (404,161 kilometers from Earth), 20h36m UT
4 The Moon passes 0.6° south of Antares, 2h UT
6 Saturn passes 1.1° south of Neptune, 10h UT
7 Asteroid Pallas is at opposition, 21h UT
8 The Moon passes 0.009° north of Pluto, 5h UT
9 Full Moon occurs at 7h55m UT
10 Mercury is stationary, 18h UT
11 Asteroid Julia is at opposition, 9h UT
12 Venus passes 0.9° south of Jupiter, 8h UT
The Moon passes 4° north of Saturn, 15h UT
The Moon passes 3° north of Neptune, 16h UT
14 The Moon is at perigee (369,288 kilometers from Earth), 17h59m UT
16 Dwarf planet Ceres is stationary, 1h UT
Last Quarter Moon occurs at 5h12m UT
The Moon passes 5° north of Uranus, 20h UT
19 Mercury is at greatest western elongation (19°), 10h UT
The Moon passes 5° north of Jupiter, 21h UT
20 The Moon passes 5° north of Venus, 11h UT
21 Venus passes 7° south of Pollux, 9h UT
The Moon passes 4° north of Mercury, 16h UT
23 New Moon occurs at 6h07m UT
26 Asteroid Hebe is at opposition, 14h UT
The Moon passes 3° south of Mars, 17h UT
27 The Moon passes 1.2° south of Spica, 15h UT
29 The Moon is at apogee (404,548 kilometers from Earth), 15h34m UT
31 First Quarter Moon occurs at 6h25m UT
The Moon passes 0.7° south of Antares, 11h UT

EXPLORE THE UNIVERSE



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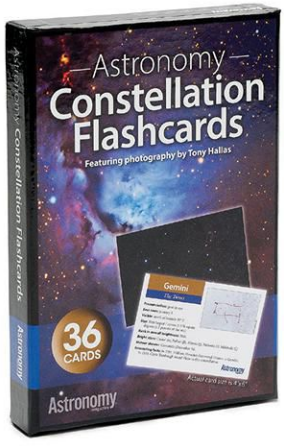

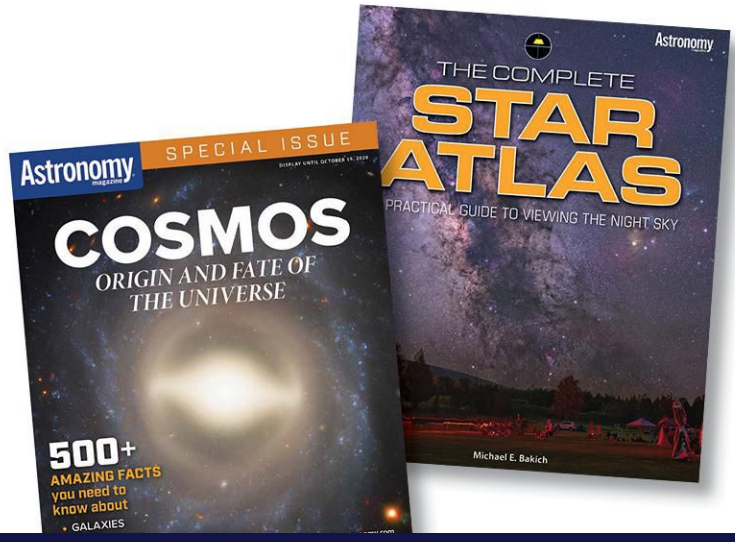

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